

FINAL REPORT

Volume II

Exposure Assessment for Polychlorinated
Biphenyls (PCBs): Incidental Production,
Recycling, and Selected Authorized Uses

Appendix A : Generic Exposure Scenarios

EPA Contract No. 68-01-6271
Task 21

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May 2, 1984

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Appendix A

Generic Exposure Scenarios

INTRODUCTION AND SUMMARY

This appendix presents a series of assessments of hypothetical occupational, consumer, and general population exposures to incidentally produced PCBs. It was prepared by Versar Inc. under Task 21 of EPA Contract No. 68-01-6271.

The primary purpose of the assessments in this appendix is to estimate maximum probable human exposures to incidentally produced and recycled PCBs under various settings or scenarios. Appendix A also provides an exposure assessment for the authorized use of PCBs in natural gas pipelines (Attachment Z). The generic exposure scenarios are based largely on engineering and scientific judgment because much of the data required to assess real-life exposures to incidentally produced PCBs are unavailable. Although not all theoretically possible exposure scenarios are addressed in this report, scenarios addressing selected occupational exposures via inhalation and dermal routes, consumer exposures via inhalation, ingestion and dermal routes, and general population exposures via inhalation and ingestion are included.

Twenty-six sets of generic exposure scenarios, presented as Attachments A through Z in this appendix, address both hypothetical exposures to PCBs in the workplace and hypothetical exposures to PCBs in the ambient environment resulting from hypothetical industrial releases of PCBs in air, water, and solid waste. Ten sets of generic exposure scenarios, presented as Attachments Z through II in this appendix, address hypothetical consumer exposures to PCBs during use of products potentially containing PCBs. All human exposures that are estimated in these attachments are summarized in Table A-1.

Table A-1. Summary of Hypothetical Maximum Human Exposures to PCBs That are Incidentally Produced, Recycled, or in Natural Gas

| Exposure type | Exposure scenario | Reference attachment ^a | Estimated individual exposure ^b : during period of exposure (mg/kg/day) | lifetime average (mg/kg/day) | Duration of exposure ^c (years) |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|---------------------------------------------------------------------------------------|----------------------------------------------------------------------|-------------------------------------------|
| Ambient inhalation | ● <u>Reference scenarios</u> | | | | |
| | ● Exposure at the average urban atmospheric level (5 ng/m ³) | - | 3.5x10 ⁻² | 1.4x10 ⁻⁶ | 70 |
| | ● Exposure at the average rural atmospheric level (0.05 ng/m ³) | - | 3.5x10 ⁻⁴ | 1.4x10 ⁻⁸ | 70 |
| | ● Exposure at the PCB LOQ for air (10 ug/m ³) | - | 69 | 2.7x10 ⁻³ | 70 |
| | ● Exposure at a distance of 800 m (0.5 mile) downwind of a large capacity chemicals manufacturing plant with PCBs present in the process stream at: - 2 mg/kg - 25 mg/kg - 50 mg/kg | A A A | 2.4x10 ⁻³ 2.9x10 ⁻² 5.9x10 ⁻² | 9.4x10 ⁻⁸ 1.1x10 ⁻⁶ 2.3x10 ⁻⁶ | 70 70 70 |
| Ambient ingestion | ● Exposure at a distance of 800 m (0.5 mile) downwind of a large capacity industrial incinerator burning wastes containing 50 mg/kg PCBs | B | <2.4x10 ⁻² | <9.4x10 ⁻⁷ | 70 |
| | ● <u>Reference scenarios</u> | | | | |
| | ● Average adult intake of PCBs via food during 1978 as reported by FDA | H | <6.9x10 ⁻¹ | <2.7x10 ⁻⁵ | 70 |
| | ● Ingestion of fish containing 2 ppm of PCBs (i.e., the 1977 proposed FDA tolerance level for PCBs in the edible portion of fish) | H | 4.75 | 1.9x10 ⁻⁴ | 70 |

Table A-1. (continued)

| Exposure type | Exposure scenario | Reference attachment ^a | Estimated individual exposure ^b : during period of exposure (mg/kg/day) | lifetime average (mg/kg/day) | Duration of exposure ^c (years) |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|---------------------------------------------------------------------------------------|------------------------------|-------------------------------------------|
| Ambient ingestion | ● Ingestion of fish or water obtained from water bodies down stream of chemical plants discharging wastewater containing 100 ug/l of PCBs. | H | 2.7x10 ⁻⁴ to 130 | 1.1x10 ⁻⁸ | 70 |
| | | | | 5.1x10 ⁻³ | |
| Occupational inhalation | ● Ingestion of groundwater drawn from wells located down gradient from a landfill receiving wastes containing 50 mg/kg PCBs | C | <7.7x10 ⁻⁶ | <3.0x10 ⁻¹⁰ | 70 |
| | | | | <3.0x10 ⁻¹⁰ | |
| Occupational inhalation | ● <u>Reference scenarios</u> | | | | |
| | ● Exposure at the OSHA standard for PCBs in air (1,000 ug/m ³) | - | 2.3x10 ³ | 9.0x10 ⁻² | 38.5 |
| | ● Exposure at the LOQ for PCBs in air (10 ug/m ³) | - | 23 | 9.0x10 ⁻⁴ | 38.5 |
| | ● Exposure at the NIOSH recommended standard for PCBs in air (1 ug/m ³) | - | 2.3 | 9.0x10 ⁻⁵ | 38.5 |
| | ● <u>Transfer and handling operation scenarios</u> | | | | |
| Occupational inhalation | ● Loading/unloading a liquid assuming PCBs are present in the liquid at: - 2 mg/kg - 25 mg/kg - 50 mg/kg | K | 5.0x10 ⁻³ | 2.0x10 ⁻⁷ | 38.5 |
| | | | | 2.3x10 ⁻⁶ | 38.5 |
| | | | | 1.2x10 ⁻¹ | 38.5 |
| | | | | 4.7x10 ⁻⁶ | 38.5 |

Table A-1. (continued)

| Exposure type | Exposure scenario | Reference attachment ^a | Estimated individual exposure ^b : during period of exposure (mg/kg/day) | lifetime average (mg/kg/day) | Duration of exposure ^c (years) |
|-------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|---------------------------------------------------------------------------------------|------------------------------|-------------------------------------------|
| Occupational inhalation | ● Loading/unloading a powder assuming PCBs are present in the powder at: | | | | |
| | - 2 mg/kg | K | 2.2x10 ⁻³ | 8.6x10 ⁻⁸ | 38.5 |
| | - 25 mg/kg | K | 2.9x10 ⁻² | 1.1x10 ⁻⁶ | 38.5 |
| | - 50 mg/kg | K | 5.7x10 ⁻² | 2.2x10 ⁻⁶ | 38.5 |
| | ● Loading/unloading a powder assuming compliance with the OSHA nuisance dust standard and assuming PCBs are present in the powder at: | | | | |
| 4 | - 2 mg/kg | F | 6.9x10 ⁻² | 2.7x10 ⁻⁶ | 38.5 |
| | - 25 mg/kg | F | 8.8x10 ⁻¹ | 3.4x10 ⁻⁵ | 38.5 |
| | - 50 mg/kg | F | 1.7 | 6.7x10 ⁻⁵ | 38.5 |
| Occupational inhalation | ● <u>Process operation scenarios</u> | | | | |
| | ● Exposures to background levels of fugitive emissions in enclosed chemical manufacturing plants assuming PCBs are present in the process stream at: | | | | |
| | - 2 mg/kg | M | 2.1x10 ⁻¹ | 8.2x10 ⁻⁶ | 38.5 |
| | - 25 mg/kg | M | 2.6 | 1.1x10 ⁻⁴ | 38.5 |
| | - 50 mg/kg | M | 5.3 | 2.1x10 ⁻⁴ | 38.5 |

Table A-1. (continued)

| Exposure type | Exposure scenario | Reference attachment ^a | Estimated individual exposure during period of exposure (mg/kg/day) | lifetime average exposure ^b (mg/kg/day) | Duration of exposure ^c (years) |
|-------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|---------------------------------------------------------------------|----------------------------------------------------|-------------------------------------------|
| Occupational inhalation | <ul style="list-style-type: none"> Exposure to fugitive emissions for a worker stationed six meters downwind of leaking equipment assuming PCBs are present in the emitted chemical at: <ul style="list-style-type: none"> - 2 mg/kg - 25 mg/kg - 50 mg/kg | N | 7.4x10 ⁻² | 1.6x10 ⁻⁶ | 38.5 |
| | | N | 9.2x10 ⁻¹ | 2.0x10 ⁻⁵ | 38.5 |
| | | N | 1.9 | 4.1x10 ⁻⁵ | 38.5 |
| Occupational inhalation | <ul style="list-style-type: none"> Exposure during open-surface tank operations (e.g., degreasing tank) assuming tank liquid temperature of 75°C and assuming PCBs are present in the liquid at: <ul style="list-style-type: none"> - 2 mg/kg - 25 mg/kg - 50 mg/kg | Q | 5.1x10 ⁻³ | 1.1x10 ⁻⁷ | 38.5 |
| | | Q | 6.5x10 ⁻² | 1.4x10 ⁻⁶ | 38.5 |
| | | Q | 1.3x10 ⁻¹ | 2.8x10 ⁻⁶ | 38.5 |
| Occupational inhalation | <ul style="list-style-type: none"> Exposure to evaporative emissions during non-spray coating operations assuming a coating temperature of 75°C and assuming PCBs are present in the coating at: <ul style="list-style-type: none"> - 2 mg/kg - 25 mg/kg - 50 mg/kg | S | 3.7x10 ⁻² | 8.0x10 ⁻⁷ | 38.5 |
| | | S | 4.6x10 ⁻¹ | 9.9x10 ⁻⁶ | 38.5 |
| | | S | 9.2x10 ⁻¹ | 2.0x10 ⁻⁵ | 38.5 |

Table A-1. (continued)

| Exposure type | Exposure scenario | Reference attachment ^a | Estimated individual exposure ^b : | | Duration of exposure ^c (years) |
|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|----------------------------------------------|------------------------------|-------------------------------------------|
| | | | during period of exposure (mg/yr) | lifetime average (mg/kg/day) | |
| Occupational inhalation | <ul style="list-style-type: none"> Exposure to paint mists during spray painting assuming PCBs are present in the binder at: | | | | |
| | - 2 mg/kg | 0 | 4.4×10^{-2} | 1.7×10^{-6} | 38.5 |
| | - 25 mg/kg | 0 | 5.5×10^{-1} | 2.2×10^{-5} | 38.5 |
| | - 50 mg/kg | 0 | 1.1 | 4.3×10^{-5} | 38.5 |
| Occupational inhalation | <ul style="list-style-type: none"> Exposure to paint mists during spray painting assuming PCBs are present in the solvent at: | | | | |
| | - 2 mg/kg | 0 | 5.2×10^{-2} | 2.0×10^{-6} | 38.5 |
| | - 25 mg/kg | 0 | 6.4×10^{-1} | 2.5×10^{-5} | 38.5 |
| | - 50 mg/kg | 0 | 1.3 | 5.0×10^{-5} | 38.5 |
| Occupational inhalation | <ul style="list-style-type: none"> Exposure to paint mists during spray painting assuming PCBs are present in the pigment toner at: | | | | |
| | - 2 mg/kg | 0 | 2.6×10^{-3} | 1.0×10^{-7} | 38.5 |
| | - 25 mg/kg | 0 | 3.2×10^{-2} | 1.3×10^{-6} | 38.5 |
| | - 50 mg/kg | 0 | 6.4×10^{-2} | 2.5×10^{-6} | 38.5 |
| Occupational inhalation | <ul style="list-style-type: none"> Exposure to evaporation emissions during liquid product formulation assuming a liquid temperature of 25°C, open formulation tanks, and PCB concentrations in the liquid at: | | | | |
| | - 2 mg/kg | R | 2.1×10^{-4} | 8.2×10^{-9} | 38.5 |
| | - 25 mg/kg | R | 2.5×10^{-3} | 9.8×10^{-8} | 38.5 |
| | - 50 mg/kg | R | 5.3×10^{-3} | 2.1×10^{-7} | 38.5 |

Table A-1. (continued)

| Exposure type | Exposure scenario | Reference attachment ^a | Estimated individual exposure during period of exposure (mg/kg/day) | Estimated individual exposure: lifetime average (mg/kg/day) | Duration of exposure ^c (years) |
|-------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|---------------------------------------------------------------------|-------------------------------------------------------------|-------------------------------------------|
| Occupational inhalation | <ul style="list-style-type: none"> Exposure to mists during air-blast pesticide spraying assuming PCBs are present in the active pesticide ingredient at: <ul style="list-style-type: none"> - 2 mg/kg - 25 mg/kg - 50 mg/kg | T | 6.7x10 ⁻⁵ | 1.4x10 ⁻⁹ | 38.5 |
| | | T | 8.6x10 ⁻⁴ | 1.8x10 ⁻⁸ | 38.5 |
| | | T | 1.7x10 ⁻³ | 3.7x10 ⁻⁸ | 38.5 |
| | <ul style="list-style-type: none"> Exposure to evaporative emissions during grain fumigation assuming PCBs are present in the fumigant at: <ul style="list-style-type: none"> - 2 mg/kg - 25 mg/kg - 50 mg/kg | J | <1.3x10 ⁻² | <2.8x10 ⁻⁷ | 38.5 |
| | | J | <1.7x10 ⁻¹ | <3.6x10 ⁻⁶ | 38.5 |
| | | J | <3.3x10 ⁻¹ | <7.1x10 ⁻⁶ | 38.5 |
| | <ul style="list-style-type: none"> Exposure to oil mists during operations such as printing and metalworking assuming compliance with the OSHA standard for mineral oil mist and assuming PCBs are present in the oil at: <ul style="list-style-type: none"> - 2 mg/kg - 25 mg/kg - 50 mg/kg | P | 2.3x10 ⁻² | 5.0x10 ⁻⁷ | 38.5 |
| | | P | 2.9x10 ⁻¹ | 6.2x10 ⁻⁶ | 38.5 |
| | | P | 5.8x10 ⁻¹ | 1.2x10 ⁻⁵ | 38.5 |
| | <ul style="list-style-type: none"> Exposure to evaporative emissions during foamed plastics manufacturing operations assuming PCBs are present in the blowing agent (which constitutes ~ 17 percent by weight of the foam formulation) at: <ul style="list-style-type: none"> - 2 mg/kg - 25 mg/kg - 50 mg/kg | G | 7.7x10 ⁻³ | 1.6x10 ⁻⁷ | 38.5 |
| | | G | 1.0x10 ⁻¹ | 2.2x10 ⁻⁶ | 38.5 |
| | | G | 1.9x10 ⁻¹ | 4.1x10 ⁻⁶ | 38.5 |

Table A-1. (continued)

| Exposure type | Exposure scenario | Reference attachment ^a | Estimated individual exposure ^b : during period of exposure (mg/kg/day) | lifetime average (mg/kg/day) | Duration of exposure ^c (years) |
|-------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|---------------------------------------------------------------------------------------|------------------------------|-------------------------------------------|
| Occupational inhalation | <ul style="list-style-type: none"> Exposure to evaporative emissions during plastic manufacturing operations assuming PCBs are present in the plastic at: <ul style="list-style-type: none"> 2 mg/kg 25 mg/kg 50 mg/kg | G | 5.8x10 ⁻² | 1.2x10 ⁻⁶ | 38.5 |
| | | G | 7.1x10 ⁻¹ | 2.3x10 ⁻⁶ | 38.5 |
| | | G | 1.4 | 2.8x10 ⁻⁵ | 38.5 |
| | | | | 5.5x10 ⁻⁵ | 38.5 |
| ∞ | <ul style="list-style-type: none"> Exposure during manufacture of asphalt roofing products | V | <2.3x10 ⁻¹ | <9.0x10 ⁻⁶ | 38.5 |
| | | | to 6.4 | to 2.5x10 ⁻⁴ | 1.4x10 ⁻⁴ |
| | | | | | |
| | <ul style="list-style-type: none"> Exposure to evaporative emissions during paper manufacturing assuming PCBs are present in waste-paper furnish at: <ul style="list-style-type: none"> 12 mg/kg 5 mg/kg 2.5 mg/kg | W | 9.2x10 ⁻¹ | 3.6x10 ⁻⁵ | 38.5 |
| | | W | 3.9x10 ⁻¹ | 1.5x10 ⁻⁵ | 38.5 |
| | | W | 2.0x10 ⁻² | 7.8x10 ⁻⁷ | 38.5 |
| | <ul style="list-style-type: none"> Exposure to evaporative emissions during paper manufacturing assuming PCBs are present in the printed ink of wastepaper furnish at: <ul style="list-style-type: none"> 2 mg/kg 25 mg/kg 50 mg/kg | W | 6.0x10 ⁻⁴ | 2.4x10 ⁻⁸ | 38.5 |
| | | W | 7.5x10 ⁻³ | 2.9x10 ⁻⁷ | 38.5 |
| | | W | 1.5x10 ⁻² | 5.9x10 ⁻⁷ | 38.5 |
| | <ul style="list-style-type: none"> Exposure during rerefining of waste oil assuming PCBs are present in the waste oil at: <ul style="list-style-type: none"> 2 mg/kg 25 mg/kg 50 mg/kg | X | 7.8x10 ⁻³ | 1.7x10 ⁻⁷ | 38.5 |
| | | X | 9.7x10 ⁻² | 3.0x10 ⁻⁷ | 38.5 |
| | | X | 1.9x10 ⁻¹ | 3.8x10 ⁻⁶ | 38.5 |
| | | | | 7.4x10 ⁻⁶ | 4.1x10 ⁻⁶ |

Table A-1. (continued)

| Exposure type | Exposure scenario | Reference attachment ^a | Estimated individual exposure ^b : | | Duration of exposure ^c (years) |
|-------------------------|-------------------------------------------------------------------------------------------------------|-----------------------------------|----------------------------------------------|------------------------------|-------------------------------------------|
| | | | during period of exposure (mg/yr) | lifetime average (mg/kg/day) | |
| Occupational inhalation | ● Exposure during garment dry cleaning operations assuming PCBs are present in the cleaning fluid at: | | | | |
| | - 2 mg/kg | U | 1.2x10 ⁻³ | 4.7x10 ⁻⁸ | 38.5 |
| | - 25 mg/kg | U | 1.6x10 ⁻² | 6.3x10 ⁻⁷ | 38.5 |
| | - 50 mg/kg | U | 3.7x10 ⁻² | 1.3x10 ⁻⁶ | 38.5 |
| | ● <u>Sampling and maintenance operation scenarios</u> | | | | |
| | ● Exposure during on-line repair of equipment leaking gas/fluid containing PCBs at: | | | | |
| ○ | - 2 mg/kg | L | 1.4x10 ⁻² | 5.5x10 ⁻⁷ | 38.5 |
| | - 25 mg/kg | L | 1.7x10 ⁻¹ | 6.6x10 ⁻⁶ | 38.5 |
| | - 50 mg/kg | L | 3.3x10 ⁻¹ | 1.3x10 ⁻⁵ | 38.5 |
| | ● Exposure during sampling assuming the process stream contains PCBs at: | | | | |
| ○ | - 2 mg/kg | D | 2.9x10 ⁻¹ | 1.1x10 ⁻⁵ | 38.5 |
| | - 25 mg/kg | D | 3.6 | 1.4x10 ⁻⁴ | 38.5 |
| | - 50 mg/kg | D | 7.2 | 2.8x10 ⁻⁴ | 38.5 |
| | ● Exposure while cleaning equipment containing a fluid in which PCBs are assumed to be present at: | | | | |
| ○ | - 2 mg/kg | D | 3.9x10 ⁻² | 1.5x10 ⁻⁶ | 38.5 |
| | - 25 mg/kg | D | 5.0x10 ⁻¹ | 2.0x10 ⁻⁵ | 38.5 |
| | - 50 mg/kg | D | 9.9x10 ⁻¹ | 4.0x10 ⁻⁵ | 38.5 |

Table A-1. (continued)

| Exposure type | Exposure scenario | Reference attachment ^a | Estimated individual exposure ^b : | | Duration of exposure ^c (years) |
|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|----------------------------------------------|----------------------------------------------|-------------------------------------------|
| | | | during period of exposure (mg/yr) | lifetime average (mg/kg/day) | |
| Occupational inhalation | <ul style="list-style-type: none"> Exposure while repairing equipment off-line assuming the equipment contains a fluid in which PCBs are present at: | | | | |
| | - 2 mg/kg | D | 2.0x10 ⁻² | 7.8x10 ⁻⁷ | 38.5 |
| | - 25 mg/kg | D | 2.5x10 ⁻¹ | 9.8x10 ⁻⁶ | 38.5 |
| | - 50 mg/kg | D | 5.0x10 ⁻¹ | 1.9x10 ⁻⁵ | 38.5 |
| | <ul style="list-style-type: none"> Exposure during filter removal assuming PCBs are present at: | | | | |
| | - 2 mg/kg | D | 9.8x10 ⁻³ | 3.8x10 ⁻⁷ | 38.5 |
| | - 25 mg/kg | D | 1.3x10 ⁻¹ | 5.1x10 ⁻⁶ | 38.5 |
| | - 50 mg/kg | D | 2.5x10 ⁻¹ | 9.8x10 ⁻⁶ | 38.5 |
| | <ul style="list-style-type: none"> Exposure during removal of still bottoms assuming PCBs are present in the still bottoms at: | | | | |
| | - 200 mg/kg | D | 9.8x10 ⁻¹ | 3.8x10 ⁻⁵ | 38.5 |
| | - 2500 mg/kg | D | 13 | 5.1x10 ⁻⁴ | 38.5 |
| | - 5000 mg/kg | D | 25 | 9.8x10 ⁻⁴ | 38.5 |
| | <ul style="list-style-type: none"> Exposure during cleaning of spilled liquids assuming PCBs are present in the liquid at: | | | | |
| | - 2 mg/kg | D | 1.6x10 ⁻⁴ | 6.3x10 ⁻⁹ | 38.5 |
| | - 25 mg/kg | D | 2.0x10 ⁻³ | 7.8x10 ⁻⁸ | 38.5 |
| | - 50 mg/kg | D | 4.2x10 ⁻³ | 1.6x10 ⁻⁷ | 38.5 |
| | <ul style="list-style-type: none"> Exposure during removal of condensate and cleanup of spills: natural gas pipelines | | | | |
| | - 2 mg/kg | Z | 1.3x10 ⁻³ to 2.5x10 ⁻² | 5.1x10 ⁻⁸ to 9.8x10 ⁻⁷ | 38.5 |
| | - 25 mg/kg | Z | 1.6x10 ⁻² to 3.2x10 ⁻¹ | 6.3x10 ⁻⁷ to 1.3x10 ⁻⁵ | 38.5 |
| | - 50 mg/kg | Z | 3.3x10 ⁻² to 6.7x10 ⁻¹ | 1.3x10 ⁻⁶ to 2.6x10 ⁻⁵ | 38.5 |

Table A-1. (continued)

Occupational dermal

| Exposure scenario | Reference attachment ^a | Estimated individual exposure ^b : | | | | | | | Duration of exposure ^c (years) | | |
|-------------------------------------------|-----------------------------------|----------------------------------------------|----------|---------------------------------------|----------------------|------------------------------|----------------------|----------------------|-------------------------------------------|----------------------|------|
| | | during period of exposure (mg/yr) | | during period of exposure (mg/kg/day) | | lifetime average (mg/kg/day) | | | | | |
| | | PCB concentration | | PCB concentration | | PCB concentration | | | | | |
| | | 50 mg/kg | 25 mg/kg | 2 mg/kg | 50 mg/kg | 25 mg/kg | 2 mg/kg | 50 mg/kg | 25 mg/kg | 2 mg/kg | |
| <u>Transfer and handling operations</u> | | | | | | | | | | | |
| ● Loading/unloading liquid | Y | 12 | 6.0 | 0.48 | 4.7x10 ⁻⁴ | 2.4x10 ⁻⁴ | 1.9x10 ⁻⁵ | 2.6x10 ⁻⁴ | 1.3x10 ⁻⁴ | 1.0x10 ⁻⁵ | 38.5 |
| ● Loading/unloading powder | Y | 12 | 5.8 | 0.46 | 4.7x10 ⁻⁴ | 2.4x10 ⁻⁴ | 1.9x10 ⁻⁵ | 2.6x10 ⁻⁴ | 1.2x10 ⁻⁴ | 9.9x10 ⁻⁶ | 38.5 |
| <u>Processing operations</u> | | | | | | | | | | | |
| ● Closed process operations | Y | 6.0 | 3.0 | 0.24 | 2.3x10 ⁻⁴ | 1.2x10 ⁻⁴ | 9.4x10 ⁻⁶ | 1.3x10 ⁻⁴ | 6.4x10 ⁻⁵ | 5.2x10 ⁻⁶ | 38.5 |
| ● Open surface tank operations | Y | 30 | 15 | 1.2 | 1.2x10 ⁻³ | 5.9x10 ⁻⁴ | 4.7x10 ⁻⁵ | 6.4x10 ⁻⁴ | 3.2x10 ⁻⁴ | 2.6x10 ⁻⁵ | 38.5 |
| ● Spray painting operations | Y | 30 | 15 | 1.2 | 1.2x10 ⁻³ | 5.9x10 ⁻⁴ | 4.7x10 ⁻⁵ | 6.4x10 ⁻⁴ | 3.2x10 ⁻⁴ | 2.6x10 ⁻⁵ | 38.5 |
| ● Grain fumigation operations | Y | 30 | 15 | 1.2 | 1.2x10 ⁻³ | 5.9x10 ⁻⁴ | 4.7x10 ⁻⁵ | 6.4x10 ⁻⁴ | 3.2x10 ⁻⁴ | 2.6x10 ⁻⁵ | 38.5 |
| ● Air-blast pesticide spraying operations | Y | 0.82 | 0.41 | 0.033 | 3.2x10 ⁻⁵ | 1.6x10 ⁻⁵ | 1.3x10 ⁻⁶ | 1.8x10 ⁻⁵ | 8.8x10 ⁻⁶ | 7.1x10 ⁻⁷ | 38.5 |
| ● Non-spray coating operations | Y | 30 | 15 | 1.2 | 1.2x10 ⁻³ | 5.9x10 ⁻⁴ | 4.7x10 ⁻⁵ | 6.4x10 ⁻⁴ | 3.2x10 ⁻⁴ | 2.6x10 ⁻⁵ | 38.5 |
| ● Product formulation operations | Y | 12 | 6.0 | 0.48 | 4.7x10 ⁻⁴ | 2.4x10 ⁻⁴ | 1.9x10 ⁻⁵ | 2.6x10 ⁻⁴ | 1.3x10 ⁻⁴ | 1.0x10 ⁻⁵ | 38.5 |

Occupational dermal

Table A-1. (continued)

| Exposure scenario | Reference attachment ^a | Estimated individual exposure ^b : | | | | | | Duration of exposure ^c (years) | | | |
|--------------------------------------------|-----------------------------------|----------------------------------------------|----------|---------------------------------------|----------------------|------------------------------|----------------------|-------------------------------------------|----------------------|----------------------|------|
| | | during period of exposure (mg/yr) | | during period of exposure (mg/kg/day) | | lifetime average (mg/kg/day) | | | | | |
| | | PCB concentration | | PCB concentration | | PCB concentration | | | | | |
| | | 50 mg/kg | 25 mg/kg | 2 mg/kg | 50 mg/kg | 25 mg/kg | 2 mg/kg | 50 mg/kg | 25 mg/kg | 2 mg/kg | |
| ● Product fabrication operations | | | | | | | | | | | |
| ● Metalworking operations | Y | 30 | 15 | 1.2 | 1.2x10 ⁻³ | 5.9x10 ⁻⁴ | 4.7x10 ⁻⁵ | 6.4x10 ⁻⁴ | 3.2x10 ⁻⁴ | 2.6x10 ⁻⁵ | 38.5 |
| ● Newspaper production | Y | 30 | 15 | 1.2 | 1.2x10 ⁻³ | 5.9x10 ⁻⁴ | 4.7x10 ⁻⁵ | 6.4x10 ⁻⁴ | 3.2x10 ⁻⁴ | 2.6x10 ⁻⁵ | 38.5 |
| ● Plastics manufacture | Y | 30 | 15 | 1.2 | 1.2x10 ⁻³ | 5.9x10 ⁻⁴ | 4.7x10 ⁻⁵ | 6.4x10 ⁻⁴ | 3.2x10 ⁻⁴ | 2.6x10 ⁻⁵ | 38.5 |
| ● Dry cleaning of garments | Y | 30 | 15 | 1.2 | 1.2x10 ⁻³ | 5.9x10 ⁻⁴ | 4.7x10 ⁻⁵ | 6.4x10 ⁻⁴ | 3.2x10 ⁻⁴ | 2.6x10 ⁻⁵ | 38.5 |
| <u>Sampling and maintenance operations</u> | | | | | | | | | | | |
| ● On-line repair of leaking equipment | Y | 0.50 | 0.25 | 0.020 | 2.0x10 ⁻⁵ | 9.8x10 ⁻⁶ | 7.8x10 ⁻⁷ | 1.1x10 ⁻⁵ | 5.4x10 ⁻⁶ | 4.3x10 ⁻⁷ | 38.5 |
| ● Sampling process stream | Y | 30 | 15 | 1.2 | 1.2x10 ⁻³ | 5.9x10 ⁻⁴ | 4.7x10 ⁻⁵ | 6.4x10 ⁻⁴ | 3.2x10 ⁻⁴ | 2.6x10 ⁻⁵ | 38.5 |
| ● Cleaning equipment | Y | 6.0 | 3.0 | 0.24 | 2.3x10 ⁻⁴ | 1.2x10 ⁻⁴ | 9.4x10 ⁻⁶ | 1.3x10 ⁻⁴ | 6.4x10 ⁻⁵ | 5.2x10 ⁻⁶ | 38.5 |
| ● Off-line repair of equipment | Y | 3.0 | 1.5 | 0.12 | 1.2x10 ⁻⁴ | 5.9x10 ⁻⁵ | 4.7x10 ⁻⁶ | 6.4x10 ⁻⁵ | 3.2x10 ⁻⁵ | 2.6x10 ⁻⁶ | 38.5 |
| ● Removing filters | Y | 6.0 | 3.0 | 0.24 | 2.3x10 ⁻⁴ | 1.2x10 ⁻⁴ | 9.4x10 ⁻⁶ | 1.3x10 ⁻⁴ | 6.4x10 ⁻⁵ | 5.2x10 ⁻⁶ | 38.5 |
| ● Removing still bottoms | Y | 6.0 | 3.0 | 0.24 | 2.3x10 ⁻⁴ | 1.2x10 ⁻⁴ | 9.4x10 ⁻⁶ | 1.3x10 ⁻⁴ | 6.4x10 ⁻⁵ | 5.2x10 ⁻⁶ | 38.5 |
| ● Spill cleanup | Y | 1.5 | 0.75 | 0.060 | 5.9x10 ⁻⁵ | 2.9x10 ⁻⁵ | 2.3x10 ⁻⁶ | 3.2x10 ⁻⁶ | 1.6x10 ⁻⁵ | 1.3x10 ⁻⁶ | 38.5 |

Occupational dermal

Table A-1. (continued)

| Exposure scenario | Reference attachment ^a | Estimated individual exposure ^b : | | | | Duration of exposure ^c (years) |
|----------------------------------------------------------------------|-----------------------------------|----------------------------------------------|---------------------------------------|----------------------------------------------|----------------------------------------------|----------------------------------------------|
| | | during period of exposure (mg/yr) | during period of exposure (mg/kg/day) | lifetime average (mg/kg/day) | | |
| | | <u>PCB concentration</u> | | | | |
| | | <u>PCB concentration</u> | | | | |
| | | <u>PCB concentration</u> | | | | |
| ● Removal of condensate and cleanup of spills: natural gas pipelines | 50 mg/kg | 25 mg/kg | 2 mg/kg | 50 mg/kg | 2 mg/kg | 2 mg/kg |
| | 0.84 to 16.7 | 0.42 to 8.4 | 0.033 to 0.67 | 3.3x10 ⁻⁴ to 6.5x10 ⁻⁴ | 1.6x10 ⁻⁵ to 3.3x10 ⁻⁴ | 1.3x10 ⁻⁶ to 2.6x10 ⁻⁵ |
| | | | | | | |
| | | | | | | |

Table A-1. (continued)

| Exposure type | Exposure scenario | Reference attachment ^a | Estimated individual exposure: | | Duration of exposure ^c (years) |
|---------------------|-------------------------------------------------------------------------------------------------------------------|-----------------------------------|-----------------------------------|------------------------------|-------------------------------------------|
| | | | during period of exposure (mg/yr) | lifetime average (mg/kg/day) | |
| Consumer inhalation | ● Exposure resulting from residential use of natural gas, assuming the PCB concentration in natural gas is: | | | | |
| | - 8 ug/m ³ | Z | 0.1 | 3.8x10 ⁻⁶ | 70 |
| | - 41 ug/m ³ | Z | 0.5 | 2.0x10 ⁻⁵ | 70 |
| | ● Exposure resulting from use of space deodorants assuming PCBs are present in the product at: | | | | |
| | - 2 mg/kg | AA | 1.3x10 ⁻² | 5.1x10 ⁻⁷ | 70 |
| | - 25 mg/kg | AA | 1.7x10 ⁻¹ | 6.7x10 ⁻⁶ | 70 |
| | - 50 mg/kg | AA | 3.3x10 ⁻¹ | 1.3x10 ⁻⁵ | 70 |
| | ● Exposure resulting from use of moth control products assuming PCBs are present in the product at: | | | | |
| | - 2 mg/kg | AA | 2.6x10 ⁻³ | 1.0x10 ⁻⁷ | 70 |
| | - 25 mg/kg | AA | 3.2x10 ⁻² | 1.3x10 ⁻⁶ | 70 |
| | - 50 mg/kg | AA | 6.6x10 ⁻² | 2.6x10 ⁻⁶ | 70 |
| | ● Exposures resulting from painting the interior of a house assuming PBCs are present in the pigment at: | | | | |
| | - 2 mg/kg | DD | 1.3x10 ⁻⁵ | 5.1x10 ⁻¹⁰ | 14 |
| | - 25 mg/kg | DD | 1.7x10 ⁻⁴ | 6.7x10 ⁻⁹ | 14 |
| | - 50 mg/kg | DD | 3.3x10 ⁻⁴ | 1.3x10 ⁻⁸ | 14 |
| | - 150 mg/kg | DD | 1.0x10 ⁻³ | 3.9x10 ⁻⁸ | 14 |
| | ● Exposures resulting from painting the interior of a house assuming PCBs are present in a resin intermediate at: | | | | |
| | - 2 mg/kg | DD | 6.1x10 ⁻⁵ | 2.4x10 ⁻⁹ | 14 |
| | - 25 mg/kg | DD | 7.7x10 ⁻⁴ | 3.0x10 ⁻⁸ | 14 |
| | - 50 mg/kg | DD | 1.5x10 ⁻³ | 5.9x10 ⁻⁸ | 14 |

Table A-1. (continued)

| Exposure type | Exposure scenario | Reference attachment ^a | Estimated individual exposure ^b : during period of exposure (mg/kg/day) | lifetime average (mg/kg/day) | Duration of exposure ^c (years) |
|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|---------------------------------------------------------------------------------------|------------------------------|-------------------------------------------|
| Consumer inhalation | <ul style="list-style-type: none"> Exposures resulting from inhabiting a home with a newly painted interior assuming PCBs are present in the paint pigment at: <ul style="list-style-type: none"> - 2 mg/kg - 25 mg/kg - 50 mg/kg - 150 mg/kg | DD | 2.1x10 ⁻³ | 3.3x10 ⁻⁸ | 28 |
| | | DD | 2.6x10 ⁻² | 4.1x10 ⁻⁷ | 28 |
| | | DD | 5.1x10 ⁻² | 8.0x10 ⁻⁷ | 28 |
| | | DD | 1.6x10 ⁻¹ | 2.5x10 ⁻⁶ | 28 |
| | <ul style="list-style-type: none"> Exposures resulting from inhabiting a home with a newly painted interior assuming PCBs are present in a resin intermediate at: <ul style="list-style-type: none"> - 2 mg/kg - 25 mg/kg - 50 mg/kg | DD | 1.0x10 ⁻² | 1.6x10 ⁻⁷ | 28 |
| | | DD | 1.2x10 ⁻¹ | 1.9x10 ⁻⁶ | 28 |
| | | DD | 2.4x10 ⁻¹ | 3.8x10 ⁻⁶ | 28 |
| | | | | | |
| | <ul style="list-style-type: none"> Exposures resulting from use of spray paint assuming PCBs are present in a resin or solvent at: <ul style="list-style-type: none"> - 2 mg/kg - 25 mg/kg - 50 mg/kg | GG | 2.3x10 ⁻³ | 7.1x10 ⁻⁸ | 55 |
| | | GG | 2.9x10 ⁻² | 8.9x10 ⁻⁷ | 55 |
| | | GG | 5.8x10 ⁻² | 1.8x10 ⁻⁶ | 55 |
| | <ul style="list-style-type: none"> Exposures resulting from use of spray paints assuming PCBs are present in the pigment at: <ul style="list-style-type: none"> - 2 mg/kg - 25 mg/kg - 50 mg/kg | GG | 1.7x10 ⁻⁴ | 5.2x10 ⁻⁹ | 55 |
| | | GG | 2.2x10 ⁻³ | 6.8x10 ⁻⁸ | 55 |
| | | GG | 4.3x10 ⁻³ | 1.3x10 ⁻⁷ | 55 |

Table A-1. (continued)

| Exposure type | Exposure scenario | Reference attachment ^a | Estimated individual exposure ^b : during period of exposure (mg/kg/day) | lifetime average (mg/kg/day) | Duration of exposure ^c (years) |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Consumer inhalation | <ul style="list-style-type: none"> Exposures resulting from use of pesticide sprays assuming PCBs are present in the active ingredient at: <ul style="list-style-type: none"> - 2 mg/kg - 25 mg/kg - 50 mg/kg Exposures resulting from use of pesticide sprays assuming PCBs are present in the inert ingredients at: <ul style="list-style-type: none"> - 2 mg/kg - 25 mg/kg - 50 mg/kg Exposures resulting from use of spray cleaning/disinfectant products assuming that PCBs are present in a constituent (that accounts for 50 percent of the weight of the product) at: <ul style="list-style-type: none"> - 2 mg/kg - 25 mg/kg - 50 mg/kg Exposures resulting from inhabiting a new home containing plastic building materials which are assumed to contain PCBs at: <ul style="list-style-type: none"> - 2 mg/kg - 25 mg/kg - 50 mg/kg | GG GG GG GG GG GG GG GG GG II II II | 1.7x10 ⁻³ 2.2x10 ⁻² 4.3x10 ⁻² 8.6x10 ⁻³ 1.1x10 ⁻¹ 2.2x10 ⁻¹ 1.9x10 ⁻² 2.3x10 ⁻¹ 4.7x10 ⁻¹ 3.0x10 ⁻³ to 9.1x10 ⁻³ 4.0x10 ⁻² to 1.1x10 ⁻¹ 8.0x10 ⁻² to 2.2x10 ⁻¹ | 6.7x10 ⁻⁸ 8.6x10 ⁻⁷ 1.7x10 ⁻⁶ 3.4x10 ⁻⁷ 4.3x10 ⁻⁶ 8.6x10 ⁻⁶ 7.4x10 ⁻⁷ 9.0x10 ⁻⁶ 1.8x10 ⁻⁵ 1.2x10 ⁻⁷ to 3.6x10 ⁻⁷ 1.6x10 ⁻⁶ to 4.3x10 ⁻⁶ 3.1x10 ⁻⁶ to 8.6x10 ⁻⁶ | 55 55 55 55 55 55 55 55 55 70 70 70 |

Table A-1. (continued)

| Exposure type | Exposure scenario | Reference attachment ^a | Estimated individual exposure ^b : during period of exposure (mg/kg/day) | lifetime average (mg/kg/day) | Duration of exposure ^c (years) |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|---------------------------------------------------------------------------------------|-------------------------------------------------|-------------------------------------------|
| Consumer dermal | <ul style="list-style-type: none"> Exposures resulting from use of deodorant soaps assuming PCBs are present in the surfactant at: | | | | |
| | - 2 mg/kg | BB | 1.7x10 ⁻³ to 1.5 | 6.6x10 ⁻⁸ to 5.9x10 ⁻⁵ | 70 |
| | - 25 mg/kg | BB | 2.1x10 ⁻² to 19 | 8.2x10 ⁻⁷ to 7.4x10 ⁻⁴ | 70 |
| | - 50 mg/kg | BB | 4.2x10 ⁻² to 38 | 1.6x10 ⁻⁶ to 1.5x10 ⁻³ | 70 |
| | <ul style="list-style-type: none"> Exposures resulting from use of skin lotions assuming PCBs are present in the surfactant at: | | | | |
| | - 2 mg/kg | BB | 0.51 | 2.0x10 ⁻⁵ | 70 |
| | - 25 mg/kg | BB | 6.4 | 2.5x10 ⁻⁴ | 70 |
| | - 50 mg/kg | BB | 13 | 5.1x10 ⁻⁴ | 70 |
| | <ul style="list-style-type: none"> Exposures resulting from handling of printed matter assuming PCBs are present in the ink pigment at: | | | | |
| | - 2 mg/kg | CC | 4.7x10 ⁻³ | 1.8x10 ⁻⁷ | 60 |
| | - 25 mg/kg | CC | 5.9x10 ⁻² | 2.3x10 ⁻⁶ | 60 |
| | - 50 mg/kg | CC | 1.2x10 ⁻¹ | 4.7x10 ⁻⁶ | 60 |
| | - 150 mg/kg | CC | 3.5x10 ⁻¹ | 1.4x10 ⁻⁵ | 60 |
| | <ul style="list-style-type: none"> Exposures resulting from painting the interior of a house assuming PCBs are present in the pigment at: | | | | |
| | - 2 mg/kg | DD | 5.6x10 ⁻⁴ | 2.2x10 ⁻⁸ | 14 |
| | - 25 mg/kg | DD | 7.0x10 ⁻³ | 2.7x10 ⁻⁷ | 14 |
| | - 50 mg/kg | DD | 1.4x10 ⁻² | 5.5x10 ⁻⁷ | 14 |
| | - 150 mg/kg | DD | 4.2x10 ⁻² | 1.6x10 ⁻⁶ | 14 |

Table A-1. (continued)

| Exposure type | Exposure scenario | Reference attachment ^a | Estimated individual exposure ^b : during period of exposure (mg/kg/day) | lifetime average (mg/kg/day) | Duration of exposure ^c (years) |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|---------------------------------------------------------------------------------------|------------------------------|-------------------------------------------|
| Consumer dermal | <ul style="list-style-type: none"> Exposures resulting from painting the interior of a house assuming PCBs are present in a resin intermediate at: <ul style="list-style-type: none"> 2 mg/kg 25 mg/kg 50 mg/kg | DD | 2.6x10 ⁻³ | 1.0x10 ⁻⁷ | 14 |
| | | DD | 3.3x10 ⁻² | 1.3x10 ⁻⁶ | 14 |
| | | DD | 6.6x10 ⁻² | 2.6x10 ⁻⁶ | 14 |
| Infant | <ul style="list-style-type: none"> Exposures resulting from use of spot removers assuming PCBs are present in the product at: <ul style="list-style-type: none"> 2 mg/kg 25 mg/kg 50 mg/kg | FF | 8.4x10 ⁻³ | 3.3x10 ⁻⁷ | 55 |
| | | FF | 1.0x10 ⁻¹ | 3.9x10 ⁻⁶ | 55 |
| | | FF | 2.1x10 ⁻¹ | 8.2x10 ⁻⁶ | 55 |
| | <ul style="list-style-type: none"> Exposures resulting from use of general household cleaners assuming PCBs are present in a detergent constituent (that accounts for 25 percent by weight of the product) at: <ul style="list-style-type: none"> 2 mg/kg 25 mg/kg 50 mg/kg | FF | 1.6x10 ⁻² | 6.3x10 ⁻⁷ | 55 |
| | | FF | 2.0x10 ⁻¹ | 7.8x10 ⁻⁶ | 55 |
| | | FF | 4.0x10 ⁻¹ | 1.6x10 ⁻⁵ | 55 |
| | <ul style="list-style-type: none"> Exposures resulting from use of paint removers assuming PCBs are present in the product at: <ul style="list-style-type: none"> 2 mg/kg 25 mg/kg 50 mg/kg | FF | 1.7x10 ⁻³ | 6.6x10 ⁻⁸ | 55 |
| | | FF | 2.1x10 ⁻² | 8.2x10 ⁻⁷ | 55 |
| | | FF | 4.2x10 ⁻² | 1.6x10 ⁻⁶ | 55 |

Table A-1. (continued)

| Exposure type | Exposure scenario | Reference attachment ^a | Estimated individual exposure ^b : during period of exposure (mg/kg/day) | lifetime average (mg/kg/day) | Duration of exposure ^c (years) |
|--------------------|-----------------------------------------------------------------------------------------------------|-----------------------------------|---------------------------------------------------------------------------------------|------------------------------|-------------------------------------------|
| Consumer dermal | ● Exposures resulting from use of dyed clothing and sheets assuming PCBs are present in the dye at: | | | | |
| | - 2 mg/kg | EE | 1.1x10 ⁻³ | 4.3x10 ⁻⁸ | 70 |
| | - 25 mg/kg | EE | 1.3x10 ⁻² | 5.1x10 ⁻⁷ | 70 |
| | - 50 mg/kg | EE | 2.7x10 ⁻² | 1.1x10 ⁻⁶ | 70 |
| | - 150 mg/kg | EE | 8.1x10 ⁻² | 3.2x10 ⁻⁶ | 70 |
| Consumer ingestion | ● Exposure to foods contaminated with pesticides that contain PCBs at: | | | | |
| | - 2 mg/kg | HH | 5.1x10 ⁻⁵ | 2.0x10 ⁻⁹ | 70 |
| | - 25 mg/kg | HH | 6.4x10 ⁻⁴ | 2.5x10 ⁻⁸ | 70 |
| | - 50 mg/kg | HH | 1.3x10 ⁻³ | 5.1x10 ⁻⁸ | 70 |

^aRefer to the referenced attachment (see Appendix A) for a more detailed description of all assumptions, data, and calculations used to estimate the exposure.

^bEstimated individual exposures in terms of mg/yr were taken from the respective referenced attachment (see Appendix A). Average estimated exposures in terms of mg/kg/day were calculated for the period of exposure and also for the lifetime of the individual (assumed to be 70 years) for a 70 kg individual averaged over 365 days/year. The absorbed dose equals the exposure because 100 percent absorption is assumed for all exposure routes.

^cDuration of exposure refers to the number of years during a lifetime that the PCB exposure could be expected to occur. All occupational exposures are assumed to have a duration of 38.5 years. This is the average work life expectancy for males in the United States (personal communication between G. Schweer (Versar Inc.) and S. Smith (U.S. Department of Labor, Bureau of Labor Statistics), on April 7, 1983).

ATTACHMENT A

Hypothetical Ambient Air Levels of PCBs Resulting from Process Emissions

A.1. Introduction

The purpose of this assessment is to estimate maximum probable ambient exposure levels to PCBs potentially present in process emissions from a synthetic organic chemical manufacturing plant.

A.2. Model Plant

In order to estimate maximum probable exposure levels, some worst case assumptions have been made. The model organic chemical manufacturing plant used in this assessment is a hypothetical plant with a production capacity of 0.5×10^9 kg/yr. This plant was selected because of its very high production capacity and concomitantly high (hypothetical) PCB emission rate. To illustrate the large size of this plant, the following two pieces of comparative information are provided:

- In 1976, less than 12 percent of process units in the synthetic organic chemicals manufacturing industry had production capacities in excess of 0.5×10^9 kg/yr (USEPA 1980).
- The total estimated production of this industry in 1982 was 104×10^9 kg/yr (Versar 1982a). Thus, at full capacity, this plant could represent approximately 0.5 percent of total industry production.

It is also assumed that the plant operates at full capacity and that 0.44 percent of this production volume (i.e., 2.2×10^6 kg) is released to air in process vent emissions (Versar 1982b).

A.3. Estimation of PCB Emission Rates

The plant is assumed to be producing only chemicals whose manufacture may also incidentally generate PCBs. PCBs are assumed to be present at the same concentration in the emissions (i.e., relative to the

concentration of the intentionally produced compound) as they are in the process stream. Thus, if a PCB isomer is present at the LOQ in the process stream (i.e., 2 mg/kg), then approximately 4.4 kg of PCBs may be emitted over the course of the year (i.e., 2.2×10^6 kg \times 0.0002%). If a PCB isomer is present in the process stream at 50 mg/kg (the maximum PCB level of the many possible PCB-producing processes for which no exemption petitions have been filed), then approximately 110 kg of PCBs may be emitted annually. If it is assumed that the plant operates 24 hours per day and 365 days per year, then the PCB emission rates are 140 ug/sec at 2 mg/kg PCBs in the process stream and 3,500 ug/sec at 50 mg/kg in the process stream. If PCBs are present in the process stream at 25 mg/kg, then the PCB emission rate would be 1,700 ug/sec.

A.4. Prediction of Ambient Air Levels of PCBs

If all the emissions are considered as being released at one point, then the annual average PCB concentrations downwind from the emissions source can be estimated using the sector averaging form of the Gaussian algorithm (Turner 1970) that is given by Equation A-1.

$$C = \frac{2.03Q}{X\sigma_z u} \exp. (-0.5)(H/\sigma_z)^2 \quad (A-1)$$

where:

C = predicted PCB concentration (ug/m³)

Q = PCB emission rate (ug/sec) = 140 ug/sec at 2 mg/kg PCBs in process stream
 1,700 ug/sec at 25 mg/kg PCBs in process stream
 3,500 ug/sec at 50 mg/kg PCBs in process stream

X = downwind distance (m) = 800 m (engineering judgement based on the assumption that few people are likely to reside much closer to a large organic chemicals plant than 800 m or 0.5 mile)

σ_z = vertical dispersion coefficient (m) = 26.5 for 800 m downwind distance and neutral atmospheric stability. Neutral atmospheric stability occurs with the greatest frequency and should be used to represent average long-term conditions (GSC 1982, Turner 1970).

u = mean wind speed (m/sec) = 5.5 m/sec *

H = stack height (m) = 10 m (engineering judgement)

Using Equation A-1 and the assumed conditions listed above, the predicted annual average PCB concentrations 800 m downwind of the "point" emissions source are 0.0023 ug/m^3 , 0.028 ug/m^3 , and 0.057 ug/m^3 for PCB process stream concentrations of 2 mg/kg, 25 mg/kg, and 50 mg/kg, respectively.

A.5. Prediction of PCB Ambient Air Exposures

It is unrealistic to expect that wind direction will remain constant throughout the course of the year. Therefore, maximum concentrations of PCBs will occur in different sectors surrounding the source at different times during the year. Assuming that the emissions plume is directed towards one particular sector (out of 16 potential sectors in the sector averaging model) for 15 percent of the year**, then the average annual PCB concentration in that sector would be about 0.00035 ug/m^3 , 0.0042 ug/m^3 , and 0.0085 ug/m^3 for PCB process stream concentrations of 2 mg/kg, 25 mg/kg, and 50 mg/kg, respectively[†].

*5.5 m/sec is the average U.S. wind speed determined by weighting regional average wind speeds by populations (SAI 1980).

**Based on a study of annual meteorological data, the average maximum wind direction frequency towards one sector is approximately 15% (GSC 1982).

[†]Maximum average annual concentrations were also estimated for the PCB release rates derived in Section A.3 using the computerized Atmospheric Transport and Diffusion Model. The actual climatic conditions for four U.S. cities were used as model input. The estimated concentration ranges were 0.000089 to 0.00033 ug/m^3 , 0.0011 to 0.0040 ug/m^3 , and 0.0022 to 0.0082 ug/m^3 for PCB process stream concentrations of 2 mg/kg, 25 mg/kg, and 50 mg/kg, respectively.

A person residing in that sector for 24 hours a day, 365 days a year, who has an average hourly air intake of 0.79 m^3 (Versar 1982b) would have annual PCB exposures of about 0.0024 mg, 0.029 mg, and 0.059 mg at PCB process stream concentrations of 2 mg/kg, 25 mg/kg, and 50 mg/kg, respectively (assuming that all of the PCBs inhaled are absorbed) (HERD 1982).

References

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ATTACHMENT B

Hypothetical Ambient PCB Air Levels Resulting from Incineration of PCB-Containing Process Wastes

B.1. Introduction

The purpose of this attachment is to estimate maximum probable ambient exposure levels for PCBs potentially emitted during the incineration of PCB-containing process wastes in an industrial incinerator.

B.2. Model Incinerator

The potential PCB emissions and resulting ambient air PCB concentrations are estimated below for a large model industrial incinerator with a 1,300 kg waste/hr capacity. This assumed waste capacity is approximately equal to the capacity of the largest industrial incinerator (1,282 kg/waste/hr capacity) reported in a survey of industrial incinerators operated by chemical manufacturers in North Carolina, Georgia, Illinois, Ohio, New York, and Texas (USEPA 1980). This study assumes that the model incinerator has an effective stack height of 40 m. It also assumes that the plant operates continuously and at full capacity, 24 hours per day, 330 days per year (assumes 10% downtime for maintenance).

B.3. Estimation of PCB Emission Rates

The incinerator is assumed to be handling only PCB-containing wastes. These wastes are assumed to contain 50 mg/kg PCBs. Any wastes containing 50 mg/kg or more of PCBs must be disposed of by special means in accordance with 40 CFR 761. Table B-1 presents estimates of the PCB emission rate for various degrees of incinerator destruction efficiency.

Table B-1. Estimated PCB Emission Rates

| PCB feed rate ^a (g/hr) | PCB destruction efficiency ^b (percent) | PCB emission rates ^c | |
|-----------------------------------------|---------------------------------------------------------|------------------------------------|----------|
| | | (g/hr) | (ug/sec) |
| 65 | 99 | 0.65 | 180 |
| 65 | 95 | 3.2 | 890 |
| 65 | 90 | 6.5 | 1,800 |
| 65 | 85 | 9.8 | 2,700 |
| 65 | 80 | 13 | 3,600 |
| 65 | 77 | 15 | 4,200 |

^aPCB feed rate assumes that PCBs are present in feed wastes at 50 mg/kg (or 0.005 percent). Thus, 50 mg/kg in 1,300 kg of feed waste per hour is equivalent to 65 g/hr (i.e., 0.005 percent of 1,300).

^b77% Destruction efficiency is the lowest measured PCB destruction efficiency during incineration of sewage sludge containing 50 mg/kg in a municipal incinerator (Whitmore, undated). The PCB destruction efficiency in an industrial organic chemical waste incinerator is expected to be at the high end of the listed range.

^cEmission rates are based on the assumption that the only route by which unburned PCBs are lost from the system is through the effluent gases (i.e., no association of PCBs with fly ash, bottom ash, or scrubber water occurs).

B.4. Prediction of Ambient Air Levels of PCBs

As a rough approximation, the maximum ground-level concentration will occur at the distance where $\sigma_z = \frac{1}{\sqrt{2}} H$ (σ_z = vertical dispersion coefficient; H = effective stack height) (Turner 1970). For an atmosphere of neutral stability and an effective stack height of 40 m, σ_z is 28 m, and the distance from the stack where the maximum concentration will occur is approximately 800 m (Turner 1970). The predicted PCB levels at this distance from the stack are listed in Table B-2 for the seven PCB emission rates listed in Table B-1.

The sector averaging form of the Gaussian algorithm (Equation B-1) (Turner 1970) and the assumed conditions listed below were used to estimate the annual average PCB concentration.

$$C = \frac{2.03 Q}{X \sigma_z u} \exp [(-0.5)(H/\sigma_z)^2] \quad (B-1)$$

where:

C = predicted PCB concentration (ug/m³)

Q = PCB emission rate (ug/sec)

X = downwind distance (m) = 800 m

σ_z = vertical dispersion coefficient (m) = 28 m

H = effective stack height (m) = 40 m

u = mean wind speed (m/sec) = 5.5 m/sec (i.e., the average U.S. wind speed determined by weighting regional average wind speeds by populations) (SAI 1980).

Table B-2. Predicted PCB Ambient Air Concentrations 350 m Downwind of a Large Industrial Incinerator

| PCB emission rate ^a (ug/sec) | PCB downwind concentration ^b (ug/m ³) |
|--------------------------------------------|-----------------------------------------------------------------|
| 180 | 1.1×10^{-3} |
| 890 | 5.3×10^{-3} |
| 1,800 | 1.1×10^{-2} |
| 2,700 | 1.6×10^{-2} |
| 3,600 | 2.1×10^{-2} |
| 4,200 | 2.5×10^{-2} |

^aEmission rates are taken from Table B-1.

^bPCB concentrations predicted for a distance of 800 m downwind of the stack using Equation B-1.

B.5. Prediction of PCB Ambient Air Exposures

Table B-2 presented estimated PCB concentrations 800 m downwind of the incinerator stack. It is unrealistic to expect that wind direction will remain constant throughout the course of the year. Therefore, maximum ambient air levels of PCBs will occur at different sectors surrounding the incinerator at different times during the year. Assuming that the incinerator plume is directed towards one particular sector (out of 16 potential sectors in the model) 15 percent of the year*, Table B-3 presents average annual PCB concentrations in the affected sector and the average annual individual PCB exposure for persons residing in that sector.

Table B-3. Predicted Average Annual PCB Air Concentrations and Individual Exposures in an Affected Downwind Sector

| PCB emission rate ^a (ug/sec) | PCB downwind concentration ^b (ug/m ³) | Individual annual exposure ^c (mg/year) |
|-----------------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------|
| 180 | 1.6×10^{-4} | 0.001 |
| 890 | 8.0×10^{-4} | 0.005 |
| 1,800 | 1.6×10^{-3} | 0.010 |
| 2,700 | 2.4×10^{-3} | 0.015 |
| 3,600 | 3.2×10^{-3} | 0.020 |
| 4,200 | 3.8×10^{-3} | 0.024 |

^aEmission rates are taken from Table B-1

^bConcentrations calculated for a distance of 800 m downwind by multiplying the concentrations listed in Table B-2 by a factor of 0.15 (i.e., 15 percent).

^cIndividual annual exposures were estimated by assuming an average hourly air intake of 0.79 m³ (Versar 1982) and a residence time in the affected sector of 24 hours/day for 365 days/yr, and 100% absorption of the PCBs inhaled (HERD 1982). Because the incinerator will be operating 330 days/yr, the exposure will occur 330 days/yr.

*Based on a study of annual meteorological data, the average maximum wind direction frequency towards one sector is approximately 15% (GSC 1982).

References

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ATTACHMENT C

Hypothetical PCB Levels in Groundwater Resulting from Landfilling of PCB-Containing Waste

C.1. Introduction

The purpose of this attachment is to estimate maximum probable ambient exposure levels to PCBs potentially present in groundwater drinking supplies as a result of landfilling wastes containing 50 mg/kg or less of PCBs (wastes containing 50 mg/kg or more of PCBs must be disposed of by special means in accordance with 40 CFR 761). This attachment summarizes the methodology, assumptions, and results of a preliminary groundwater modeling study (GSC 1983) of PCB fate in landfills and groundwater.

This preliminary groundwater modeling study was conducted utilizing two computer fate models. The Seasonal Soil Compartment Model (SESOL) (Bonazountas and Wagner 1981) was used to model PCB fate in the soil column. The Analytical Transient One-, Two-, and Three-Dimensional Model (AT123D) (Yeh 1981) was used to model PCB fate and to estimate PCB concentrations in groundwater. These two models were selected for use because of their versatile modeling capabilities and their relative simplicity of application.

C.2. Methodology and Assumptions

C.2.1. Hypothetical Landfill Assumptions

The landfill modeled in the GSC (1983) study was a hypothetical on-site landfill for a chemical manufacturing plant. The plant was assumed to generate 9 kkg of solid waste per day* for 365 days per year

*In order to estimate the economic effects associated with implementation of the Resource Conservation and Recovery Act, USEPA (1980a) used a model plant solid waste generation rate of 9 kkg/day to represent the range of waste generation rates for 99 percent of all facilities in SIC 28 (the Chemicals and Allied Products Industry).

(1.e., 3,300 kkg/yr). All waste generated was assumed to contain PCBs at a concentration of 50 mg/kg. The landfill was assumed to have an operating lifetime of 10 years[†]. Thus, over the course of ten years, the landfill was assumed to receive 33,000 kkg of solid waste. Since the lifetime capacity of one acre of industrial landfill is typically 12,100 kkg of solid waste (USEPA 1980b), the size of a landfill needed to handle 33,000 kkg would be approximately three acres.

Based on the assumptions listed above, the monthly PCB loading rate per square centimeter of landfill was calculated using Equation C-1. The calculated PCB loading rate for a PCB concentration in the solid waste of 50 mg/kg is 125 ug/cm²-month.

$$\begin{aligned} \text{PCB loading rate} &= \frac{(12,100 \text{ kkg/acre})}{(10 \text{ yrs})} \times \frac{(1 \text{ yr})}{(12 \text{ months})} \times \frac{(2.47 \times 10^{-8} \text{ acre})}{(\text{cm}^2)} \quad (\text{C-1}) \\ &\quad \times \text{PCB concentration in waste} \end{aligned}$$

The climatic characteristics of the hypothetical landfill site were assumed to be similar to those of the northeastern United States where relatively long, wet seasons have been observed. A relatively wet climate was selected to enhance the driving force for pollutant downward transport. For comparison purposes, the study assessed PCB fate in three soil types: loamy sand, sandy clay, and clay loam. The loamy sand soil represents the most permeable and the clay loam soil the least permeable of the three types. The soil column (or unsaturated zone) was assumed to have a thickness of 3 meters, and the aquifer (or saturated zone) was assumed to have a depth of 10 meters.

C.2.2. Modeling of PCBs in the Soil Column and Groundwater

The fate of PCBs in soil is affected primarily by soil characteristics which can be broken down into two major categories: those that are associated with the unsaturated zone (soil column) and

[†]This is a typical lifetime for an industrial landfill (USEPA 1980b).

those that are associated with the saturated zone (groundwater aquifer). Because of the hydraulic discontinuity between these two zones, GSC (1982) treated the zones separately in the simulation of PCB fate in soil. The Seasonal Soil Compartment Model (SESOIL) (Bonazountas and Wagner 1981) was used to model the unsaturated zone. The analytical Transient One-, Two-, and Three-Dimensional Model (AT123D) (Yeh 1981) was used to model the saturated zone. These two models were selected for use by GSC because of their versatile modeling capabilities and their relative simplicity of application. The SESOIL output results were used as the input to the AT123D Model which calculated the resulting PCB concentrations in the groundwater aquifer.

C.3. Hypothetical PCB Concentrations in Groundwater

PCB concentrations in groundwater downgradient (i.e., in the direction of the groundwater flow) from the hypothetical landfill site were predicted for two PCB compounds of different chemical properties: monochlorobiphenyl and 2,2',3,3',6,6'-hexachlorobiphenyl. These two compounds were selected to account for the varying nature of different PCB compounds and its potential effect on the resulting PCB concentrations in groundwater.

The maximum amounts of these two PCB compounds that enter groundwater as predicted by the SESOIL Model are presented in Table C-1. As shown in Table C-1, the amount of monochlorobiphenyl that enters the groundwater decreases as the soil becomes less permeable. The hexachlorobiphenyl isomer was predicted to have not entered groundwater at all. This lack of downward movement is due mainly to the chemical nature of the hexachlorobiphenyl isomer (i.e., negligible water solubility and a very high soil adsorption coefficient) which keeps the chemical strongly attached to soil particles.

Table C-1. Predicted PCB Amounts
Entering Groundwater^a

| PCB compound | Predicted PCB amounts (mg/yr) in groundwater | | |
|---------------------------------------|----------------------------------------------|--------------------|--------------------|
| | <u>Loamy sand</u> | <u>Sandy clay</u> | <u>Clay loam</u> |
| Monochlorobiphenyl | 1.08×10^6 | 3.90×10^5 | 9.37×10^4 |
| 2,2',3,3',6,6'- Hexachlorobiphenyl | 0 | 0 | 0 |

^aSource: GSC 1983.

The monochlorobiphenyl concentration downgradient from the landfill as predicted by the AT123D Model are presented in Table C-2 for the three soil types. As shown in Table C-2, the predicted maximum monochlorobiphenyl concentration in groundwater downgradient from the landfill is 1.05×10^{-8} mg/l. If it is assumed that a person ingested two liters of this water daily, then his annual PCB exposure would be 7.7×10^{-6} mg/year.

Table C-2. Predicted Monochlorobiphenyl
Concentrations in Groundwater Four
Years After Landfill Operation ^{a,b}

| Depth below groundwater table (m) | Predicted PCB concentrations (mg/l) in groundwater at distances downgradient from the landfill site | | |
|--------------------------------------|--------------------------------------------------------------------------------------------------------|------------------------|------------------------|
| | 0.5 km | 1.0 km | 1.5 km |
| <u>Clay Loam Soil Type</u> | | | |
| 2 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 |
| <u>Sandy Clay Soil Type</u> | | | |
| 2 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 |
| <u>Loamy Sand Soil Type</u> | | | |
| 2 | 1.05×10^{-8} | 5.23×10^{-14} | 3.08×10^{-19} |
| 4 | 1.04×10^{-8} | 5.20×10^{-14} | 3.07×10^{-19} |
| 6 | 1.02×10^{-8} | 5.16×10^{-14} | 3.06×10^{-19} |
| 8 | 9.94×10^{-9} | 5.10×10^{-14} | 3.03×10^{-19} |
| 10 | 9.63×10^{-9} | 5.03×10^{-14} | 3.00×10^{-19} |

^aFour years after landfill operation, the predicted PCB concentrations had reached a steady state condition for all three soil types.

^bThe maximum concentrations predicted in groundwater directly under the landfill were: 2.71×10^{-18} for clay loam
 5.03×10^{-7} for sandy clay
 1.19×10^{-5} for loamy sand.

References

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ATTACHMENT D

Hypothetical Worker Inhalation Exposure to PCBs During Sampling and Maintenance Operations

D.1. Introduction

The purpose of this attachment is to estimate maximum probable worker exposure to PCBs that evaporate from relatively quiescent pools or films of liquids in which PCBs may be a contaminant. Operations that may involve this type of exposure include clean-up of spills, manual sampling of process streams, and maintenance operations particularly in confined spaces.* This attachment will estimate the maximum air concentrations of PCBs (i.e., when the liquid and air above the liquid are in equilibrium with respect to PCBs) to which a worker may be exposed during these operations.

D.2. Estimated PCB Air Concentrations

For those liquid operations that do not involve excessive agitation of the liquid and formation of mists, the maximum PCB concentration in air resulting from the evaporation of PCBs in the liquid can be estimated using Raoult's Law and Dalton's Law of Partial Pressures.

Raoult's Law, a basic principle in the properties of solutions, can be used to estimate the partial pressure of PCBs above the liquid. Raoult's Law states that the partial pressure of a component over a liquid solution at equilibrium is proportional to the mole fraction of the component in the solution. Mathematically, Raoult's Law can be stated as follows:

*Confined spaces can be categorized generally as those with open tops and with a depth that will restrict the natural movement of air and enclosed spaces with very limited openings for entry. Confined spaces include but are not limited to storage tanks, process vessels, degreasers, reaction vessels, and pits (NIOSH 1979).

$$\begin{array}{l} \text{(Partial pressure of} \\ \text{component} \\ \text{above the liquid)} \end{array} = \begin{array}{l} \text{(Vapor pressure} \\ \text{of component} \\ \text{in pure form)} \end{array} \times \begin{array}{l} \text{(Mole fraction} \\ \text{of the component} \\ \text{in liquid)} \end{array} \quad (D-1)$$

Once the partial pressure of PCBs above the liquid has been estimated, the maximum PCB air concentration at equilibrium can be estimated using Dalton's Law of Partial Pressures, a basic principle in the properties of gases. Dalton's Law states that the mole fraction of a gas in a mixture of gases is directly proportional to the ratio of the partial pressure of that gas to the total pressure of the system. Assuming ideal gas behavior, the air concentration of PCBs can thus be estimated as follows:

$$\begin{array}{l} \text{PCB air concentration} \\ \text{(mg/m}^3\text{)} \end{array} = \frac{(\text{VP}_{\text{PCB}}) \times (\text{MW}) \times (1000 \text{ mg/g}) \times (1000 \text{ l/m}^3)}{(R) \times (T)} \quad (D-2)$$

where,

VP_{PCB} = partial pressure of PCBs above the liquid (atm)

MW = molecular weight of PCBs (g/mole)

R = gas constant (0.08205 l-atm/mole⁰K)

T = air temperature (298°K or 25°C)

Using the above principles, the maximum air levels of PCBs that could result from evaporation of PCBs from liquids containing PCBs at concentrations of 50 mg/kg, 25 mg/kg, and 2 mg/kg were estimated for three different liquid temperatures (25°C, 50°C, and 75°C). Table D-1 presents the estimated values of the PCB partial pressure above the liquid and Table D-2 presents the estimated maximum PCB air concentrations directly above the liquid.

D.3. Estimated Annual Worker Exposure to PCBs

Table D-3 lists the maximum annual individual worker exposures to PCBs for six generic sampling and maintenance operations: (1) sampling the process streams (for quality control), (3) repairing equipment in confined spaces, (4) removing spent filters, (5) removing still bottoms

Table D-1. Hypothetical PCB Partial Pressures Above a Liquid Solution

| PCB concentration in solution ^a (mg/kg) | PCB equilibrium partial pressure above solution ^b (torr) at solution temperatures of: | | |
|-------------------------------------------------------|-----------------------------------------------------------------------------------------------------|----------------------|----------------------|
| | 25°C | 50°C | 75°C |
| 50 | 2.0×10^{-8} | 3.0×10^{-7} | 3.5×10^{-6} |
| 25 | 1.0×10^{-8} | 1.5×10^{-7} | 1.8×10^{-6} |
| 2 | 8.0×10^{-10} | 1.2×10^{-8} | 1.4×10^{-7} |

^aThe molecular weight of the liquid in which PCBs are a solute is assumed to be the same as the molecular weight of PCBs (i.e., 266.5 for Aroclor 1242 (USEPA 1981)). Thus, the mole fraction of PCBs in the liquid is the same as the listed concentration (expressed in terms of a weight fraction). If the molecular weight of the liquid is less than the molecular weight of PCBs, then the mole fraction of PCBs in the liquid and the estimated equilibrium PCB partial pressures would be lower than those listed in the table by a factor equal to the ratio of the molecular weight of the liquid to the molecular weight of PCBs.

^bEquilibrium partial pressures were estimated using Raoult's Law (see Eqn. D-1). The vapor pressures of PCBs in pure form at the four different temperatures are based on data provided in Hutzinger et al. (1974) for Aroclor 1242:

At 25°C, VP = 4×10^{-4} torr
 At 50°C, VP = 6×10^{-3} torr
 At 75°C, VP = 7×10^{-2} torr

Aroclor 1242 is a commercial mixture of PCB isomers. Molecules containing four or less chlorine atoms comprise more than 90 percent by weight of the mixture. Although the average number of chlorine atoms per molecule in the mixture is 3.1, the vapor pressure of the mixture is greater than would be expected for a pure trichlorobiphenyl because of the bias imparted by the components of lower chlorine content (Hutzinger et al. 1974). The vapor pressure of pure 2',3,4-trichlorobiphenyl at 25°C is 1.0×10^{-4} torr (Westcott et al. 1981).

Table D-2. Hypothetical Maximum PCB Air Concentrations Above Solutions

| PCB concentration in solution (mg/kg) | Maximum PCB air concentration ^a above solution (mg/m ³) at solution temperatures of: | | |
|---------------------------------------|-------------------------------------------------------------------------------------------------------------|----------------------|----------------------|
| | 25°C | 50°C | 75°C |
| 50 | 2.9×10^{-4} | 4.3×10^{-3} | 5.0×10^{-2} |
| 25 | 1.4×10^{-4} | 2.2×10^{-3} | 2.5×10^{-2} |
| 2 | 1.1×10^{-5} | 1.7×10^{-4} | 2.0×10^{-3} |

^aMaximum air concentrations were estimated using Equation D-2 assuming an ambient air temperature of 25°C. The molecular weight of PCBs was assumed to be 266.5 (i.e., the molecular weight of Aroclor 1242) (USEPA 1981).

Table D-3. Estimated Annual Individual Worker Exposure to PCBs

| Worker Activity | Duration (hours/day) | Frequency ^a (days/yr) | PCB concentration in liquid (mg/kg) | Annual individual worker exposure ^b (mg/yr) at liquid temperatures of: | | |
|----------------------------------------|----------------------|----------------------------------|-------------------------------------|-----------------------------------------------------------------------------------|----------------------|----------------------|
| | | | | 25°C | 50°C | 75°C |
| Sampling | 0.5 | 240 | 50 | 4.2x10 ⁻² | 6.2x10 ⁻¹ | 7.2 |
| | | | 25 | 2.0x10 ⁻² | 3.2x10 ⁻¹ | 3.6 |
| | | | 2 | 1.6x10 ⁻³ | 2.4x10 ⁻² | 2.9x10 ⁻¹ |
| Cleaning in confined spaces | 4 | 48 | 50 | 6.7x10 ⁻² | 9.9x10 ⁻¹ | c |
| | | | 25 | 3.2x10 ⁻² | 5.0x10 ⁻¹ | c |
| | | | 2 | 2.5x10 ⁻³ | 3.9x10 ⁻² | c |
| Repairing equipment in confined spaces | 4 | 24 | 50 | 3.3x10 ⁻² | 5.0x10 ⁻¹ | c |
| | | | 25 | 1.6x10 ⁻² | 2.5x10 ⁻¹ | c |
| | | | 2 | 1.3x10 ⁻³ | 2.0x10 ⁻² | c |
| Removing filters | 1 | 48 | 50 | 1.7x10 ⁻² | 2.5x10 ⁻¹ | c |
| | | | 25 | 8.1x10 ⁻³ | 1.3x10 ⁻¹ | c |
| | | | 2 | 6.3x10 ⁻⁴ | 9.8x10 ⁻³ | c |
| Removing still bottoms ^d | 1 | 48 | 5000 | 1.7 | 25 | c |
| | | | 2500 | 8.1x10 ⁻¹ | 13 | c |
| | | | 200 | 6.3x10 ⁻² | 9.8x10 ⁻¹ | c |
| Spill cleanup | 1 | 12 | 50 | 4.2x10 ⁻³ | c | c |
| | | | 25 | 2.0x10 ⁻³ | c | c |
| | | | 2 | 1.6x10 ⁻⁴ | c | c |

^aAssuming that a typical worker works 5 days/week, 48 weeks per year, then a frequency of 240 days is daily exposure, a frequency of 48 days is weekly exposure, and a frequency of 12 days is monthly exposure.

^bAnnual individual exposure calculated as follows:

$$(\text{annual exposure}) = (\text{duration}) \times (\text{frequency}) \times (\text{air concentration}) \times (\text{breathing rate})$$

The PCB air concentrations are listed in Table D-2. The breathing air rate was assumed to be 1.2 m³/hr (Versar 1982).

^cUnless these operations are performed automatically or semi-automatically with minimal potential for worker exposure except during equipment failure, the temperature of the equipment/process stream is not expected to be elevated.

^dFor still bottoms, the PCB concentration is assumed to be 100 times the process stream concentration.

or other process wastes, and (6) cleanup of spills. Frequency and duration of exposure were hypothesized for each operation. Workers are assumed to be exposed for the duration of the operation to the maximum PCB air concentrations listed in Table D-2 (i.e., the maximum PCB concentrations expected at the equilibrium partial pressure of PCBs). This is truly a worst case assumption for operations involving working in confined spaces because these spaces are usually purged prior to worker entry, and fresh air is typically provided to the space when it is occupied by workers (NIOSH 1979).

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ATTACHMENT E

Hypothetical PCB Workplace Air Levels Based on Compliance with Existing OSHA Standards

E.1. Introduction

The purpose of this attachment is to estimate PCB levels in workplace air based on compliance with OSHA (Occupational Safety and Health Administration) standards.

E.2. Estimated PCB Air Levels Based on Compliance with OSHA Standards

Tables E-1 and E-2 contain a list of 73 chemicals for which OSHA standards have been promulgated. All chlorinated organic compounds regulated by OSHA (68 chemicals) are listed in the tables, as well as five other OSHA-regulated, non-chlorinated compounds which hypothetically may contain incidentally produced PCBs.*

Based on the assumption that these chemicals may contain trace levels of incidentally produced PCBs, these tables list the maximum expected PCB air concentrations associated with the presence in air of the regulated chemical at the OSHA standard. The estimated PCB air concentrations listed in the two tables were derived from different sets of assumptions. The estimated concentrations listed in Table E-1 were based on the following assumptions:

*These five chemicals were listed in a memorandum from Dr. S. J. Cristol (University of Colorado) to R. A. Westin (Versar Inc) entitled, "Organic Chemical Processes Leading to Generation of Incidental Polychlorinated Biphenyls." (February 10, 1983).

- The regulated chemical is present in workplace air at the maximum time-weighted average (TWA) limit.
- PCBs are present in the process stream for the regulated chemical at 50 mg/kg (or 0.005 percent by weight), 25 mg/kg (or 0.0025 percent by weight), or 2 mg/kg (or 0.0002 percent by weight).
- PCBs are present in workplace air at the same weight proportion to the regulated chemical as in the process stream (i.e., 0.005, 0.0025 or 0.0002 percent). This situation would be expected to occur only when the regulated chemical was present in air solely because of mist or dust generation.

The estimated concentrations listed in Table E-2 were based on the following assumptions:

- The regulated chemical is present in workplace air at the maximum time-weighted average limit.
- PCBs are present in the process stream for the regulated chemical at 50 mg/kg.
- The regulated chemical and PCBs are present in air solely because of evaporation.

Table E-1. Estimated PCB Levels in Air Based on Compliance with OSHA Standards for Primary Chemicals
(Assuming that the regulated chemical is in air solely because of mist/dust generation)

| Chemical ^a | Synonym | OSHA TWA standard ^{b,c} (mg/m ³) | Estimated PCB air level ^e (ug/m ³) | | | Annual individual worker exposure ^f (mg/yr) | | |
|-----------------------------------|----------------------------|-------------------------------------------------------------|-----------------------------------------------------------------|----------------|----------------|--------------------------------------------------------------|----------------|----------------|
| | | | <u>2mg/kg</u> | <u>25mg/kg</u> | <u>50mg/kg</u> | <u>2mg/kg</u> | <u>25mg/kg</u> | <u>50mg/kg</u> |
| Allyl chloride | 1-Chloro-2-propene | 3 | 0.006 | 0.075 | 0.15 | 0.014 | 0.17 | 0.35 |
| Aldrin | | 0.25 | 0.0005 | 0.006 | 0.013 | 0.001 | 0.014 | 0.030 |
| Benzyl chloride | Alpha-chloro-toluene | 5 | 0.01 | 0.13 | 0.25 | 0.023 | 0.30 | 0.58 |
| Carbon tetrachloride | | 6.3 ^c | 0.013 | 0.16 | 0.32 | 0.030 | 0.37 | 0.74 |
| Chlordane | | 0.5 | 0.001 | 0.013 | 0.025 | 0.002 | 0.030 | 0.058 |
| Chlorinated camphene | Toxaphene | 0.5 | 0.001 | 0.013 | 0.025 | 0.002 | 0.030 | 0.058 |
| Chlorinated diphenyl oxide | Hexachlorodiphenyl oxide | 0.5 | 0.001 | 0.013 | 0.025 | 0.002 | 0.030 | 0.058 |
| Chloroacetaldehyde | | 3 ^d | 0.006 | 0.075 | 0.15 | 0.014 | 0.17 | 0.35 |
| alpha-Chloroacetophenone | Chloromethyl phenyl ketone | 0.3 | 0.0006 | 0.008 | 0.015 | 0.001 | 0.017 | 0.035 |
| Monochlorobenzene | | 350 | 0.7 | 8.8 | 18 | 1.6 | 20 | 41 |
| o-Chlorobenzylidene malononitrile | | 0.4 | 0.0008 | 0.01 | 0.02 | 0.002 | 0.023 | 0.046 |
| Chlorobromomethane | | 1,050 | 2.1 | 26 | 53 | 4.8 | 60 | 120 |
| *Chloroform | | 240 ^d | 0.48 | 6 | 12 | 1.1 | 14 | 28 |
| *1-Chloro-1-nitropropane | | 100 | 0.2 | 2.5 | 5 | 0.46 | 5.8 | 12 |
| Chloropicrin | Trichloronitromethane | 0.7 | 0.002 | 0.018 | 0.035 | 0.005 | 0.041 | 0.081 |
| *Chloroprene | 2-Chloro-1,3-butadiene | 90 | 0.18 | 2.3 | 4.5 | 0.41 | 5.3 | 10 |

Table E-1. (continued)

| Chemical ^a | Synonym | OSHA TWA standard ^{b,c} (mg/m ³) | Estimated PCB air level ^e (ug/m ³) | | | Annual individual worker exposure ^f (mg/yr) | | |
|------------------------------------|------------------------------------------|----------------------------------------------------------|--------------------------------------------------------------|---------|---------|-----------------------------------------------------------|---------|---------|
| | | | 2mg/kg | 25mg/kg | 50mg/kg | 2mgkg/ | 25mg/kg | 50mg/kg |
| *Crab herbicide | Na-2-(2,4-dichlorophenoxy) ethyl sulfate | 15 | 0.03 | 0.38 | 0.75 | 0.069 | 0.88 | 1.7 |
| 2,4-D | 2,4-Dichlorophenoxy acetic acid | 10 | 0.02 | 0.25 | 0.5 | 0.046 | 0.58 | 1.2 |
| DDT | | 1 | 0.002 | 0.025 | 0.05 | 0.005 | 0.058 | 0.12 |
| DDVP | 2,2-Dichlorovinyl dimethyl phosphate | 1 | 0.002 | 0.025 | 0.05 | 0.005 | 0.058 | 0.12 |
| o-Dichlorobenzene | | 300 ^d | 0.6 | 7.5 | 15 | 1.4 | 17 | 35 |
| p-Dichlorobenzene | | 450 | 0.9 | 11 | 22 | 2.1 | 25 | 50 |
| Dichlorodifluoromethane | | 4,950 | 9.9 | 124 | 250 | 23 | 290 | 580 |
| 1,3-Dichloro-5,5-dimethylhydantoin | | 0.2 | 0.0004 | 0.005 | 0.01 | 0.001 | 0.012 | 0.023 |
| 1,1-Dichloroethane | Ethylidene chloride | 400 | 0.8 | 10 | 20 | 1.8 | 23 | 46 |
| 1,2-Dichloroethylene | | 790 | 1.6 | 20 | 40 | 3.7 | 46 | 92 |
| *Dichloroethyl ether | Bis-2-(chloroethyl) ether | 90 ^d | 0.18 | 2.3 | 4.5 | 0.41 | 5.3 | 10 |
| *Dichlorofluoromethane | | 4,200 | 8.4 | 105 | 210 | 19 | 240 | 480 |
| *1,1-Dichloro-1-nitroethane | | 60 ^d | 0.12 | 1.5 | 3 | 0.28 | 3.5 | 6.9 |
| Dichlorotetrafluoroethane | | 7,000 | 14 | 175 | 350 | 32 | 400 | 800 |
| Dieldrin | | 0.25 | 0.0005 | 0.006 | 0.013 | 0.001 | 0.014 | 0.03 |

Table E-1. (continued)

| Chemical ^a | Synonym | OSHA TWA standard ^{b,c} (mg/m ³) | Estimated PCB air level ^e (ug/m ³) | | Annual individual worker exposure ^f (mg/yr) | | | |
|-----------------------------|-----------------------------------------------------|-------------------------------------------------------------|-----------------------------------------------------------------|---------|--------------------------------------------------------------|---------|---------|---------|
| | | | 2mg/kg | 25mg/kg | 50mg/kg | 2mg/kg | 25mg/kg | 50mg/kg |
| Dibrom | 1,2-Dibromo-2,2-dichloroethyl dimethyl phosphate | 3 | 0.006 | 0.075 | 0.15 | 0.014 | 0.17 | 0.35 |
| 1,2-Dibromo-3-chloropropane | | 0.01 ^c | 0.00002 | 0.0003 | 0.0005 | 0.00005 | 0.001 | 0.001 |
| Endrin | | 0.1 | 0.0002 | 0.0025 | 0.005 | 0.0005 | 0.006 | 0.012 |
| *Epichlorohydrin | 1, -Chloro-2,3-epoxypropane | 19 | 0.038 | 0.48 | 0.95 | 0.088 | 1.1 | 2.2 |
| Ethyl chloride | Monochloroethane | 2,600 | 5.2 | 65 | 130 | 12 | 150 | 300 |
| *Ethylene chlorohydrin | 2-Chloroethanol | 16 | 0.032 | 0.4 | 0.8 | 0.074 | 0.92 | 1.8 |
| *Ethylene dichloride | 1,2-Dichloroethane | 200 ^c | 0.4 | 5 | 10 | 0.92 | 12 | 23 |
| Fluorotrichloromethane | | 5,600 | 11 | 140 | 280 | 25 | 320 | 640 |
| Heptachlor | | 0.5 | 0.001 | 0.013 | 0.025 | 0.002 | 0.030 | 0.058 |
| Hexachloroethane | | 10 | 0.02 | 0.25 | 0.5 | 0.046 | 0.58 | 1.2 |
| Hexachlorocyclohexane | | 0.5 | 0.001 | 0.013 | 0.025 | 0.002 | 0.030 | 0.058 |
| Hexachloronaphthalene | | 0.2 | 0.0004 | 0.005 | 0.01 | 0.001 | 0.012 | 0.023 |
| *Methoxychlor | 2,2-Bis(p-methoxyphenol)- 1,1,1-trichloroethane | 15 | 0.03 | 0.38 | 0.75 | 0.069 | 0.88 | 1.7 |
| *Methyl chloride | Chloromethane | 200 ^c | 0.4 | 5 | 10 | 0.92 | 12 | 23 |
| Methyl chloroform | 1,1,1-Trichloroethane | 1,910 | 3.8 | 48 | 95 | 8.8 | 110 | 220 |

Table E-1. (continued)

| Chemical ^a | Synonym | OSHA TWA standard ^{b,c} (mg/m ³) | Estimated PCB air level ^e (ug/m ³) | | | Annual individual worker exposure ^f (mg/yr) | | |
|--------------------------------------------|-------------------------------------------------------------|-------------------------------------------------------------|-----------------------------------------------------------------|---------|---------|--------------------------------------------------------------|---------|---------|
| | | | 2mg/kg | 25mg/kg | 50mg/kg | 2mg/kg | 25mg/kg | 50mg/kg |
| *Methylene chloride | Dichloromethane | 1,740 | 3.5 | 44 | 87 | 8.1 | 100 | 200 |
| p-Nitrochlorobenzene | | 1 | 0.002 | 0.025 | 0.05 | 0.005 | 0.058 | 0.12 |
| Octachloronaphthalene | | 0.1 | 0.0002 | 0.0025 | 0.005 | 0.0005 | 0.006 | 0.012 |
| *Paraquat | 1,1'-dimethyl-4,4'-bipyridinium dichloride | 0.5 | 0.001 | 0.013 | 0.025 | 0.002 | 0.030 | 0.058 |
| Pentachloronaphthalene | | 0.5 | 0.001 | 0.013 | 0.025 | 0.002 | 0.030 | 0.058 |
| Pentachlorophenol | | 0.5 | 0.001 | 0.013 | 0.025 | 0.002 | 0.030 | 0.058 |
| Perchloromethyl mercaptan | Trichloromethyl sulfur chloride | 0.8 | 0.002 | 0.02 | 0.04 | 0.005 | 0.046 | 0.092 |
| Phosgene | Carbonyl chloride | 0.4 | 0.0008 | 0.01 | 0.02 | 0.002 | 0.023 | 0.046 |
| Propylene dichloride | 1,2-Dichloropropane | 350 | 0.7 | 8.8 | 18 | 1.6 | 20 | 41 |
| *Ronne1 | 0,0-Dimethyl 0-(2,3,5- trichlorophenyl) phosphorothioate | 15 | 0.03 | 0.38 | 0.75 | 0.069 | 0.88 | 1.7 |
| 2,4,5-T | 2,3,5-Trichlorophenoxy acetic acid | 10 | 0.02 | 0.25 | 0.5 | 0.046 | 0.58 | 1.2 |
| 1,1,2,2-Tetrachloro- 1,2-difluoroethane | | 4,170 | 8.3 | 104 | 210 | 19 | 240 | 480 |
| 1,1,1,2-Tetrachloro-2,2-difluoroethane | | 4,170 | 8.3 | 104 | 210 | 19 | 240 | 480 |
| *1,1,2,2-Tetrachloroethane | | 35 | 0.07 | 0.88 | 1.8 | 0.16 | 2.0 | 4.1 |

Table E-1. (continued)

| Chemical ^a | Synonym | OSHA TWA standard ^{b,c} (mg/m ³) | Estimated PCB air level ^e (ug/m ³) | | Annual individual worker exposure ^f (mg/yr) | |
|---------------------------------------|---------|-------------------------------------------------------------|-----------------------------------------------------------------|----------------|--------------------------------------------------------------|----------------|
| | | | <u>2mg/kg</u> | <u>25mg/kg</u> | <u>2mg/kg</u> | <u>25mg/kg</u> |
| *Tetrachloroethylene | | 680 ^c | 1.4 | 17 | 3.2 | 39 |
| Tetrachloronaphthalene | | 2 | 0.004 | 0.05 | 0.009 | 0.12 |
| 1,1,2-Trichloroethane | | 45 | 0.09 | 1.1 | 0.21 | 2.6 |
| Trichloronaphthalene | | 5 | 0.01 | 0.13 | 0.023 | 0.30 |
| 1,2,3-Trichloropropane | | 300 | 0.6 | 7.5 | 1.4 | 17 |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | | 7,600 | 15 | 190 | 35 | 440 |
| *Trichloroethylene | | 540 ^c | 1.1 | 14 | 2.5 | 32 |
| Vinyl Chloride | | 2.6 ^c | 0.005 | 0.065 | 0.012 | 0.15 |
| Ethylene diamine | | 25 | 0.05 | 0.6 | 0.1 | 1.4 |
| Propylene oxide | | 240 | 0.48 | 6 | 1.1 | 14 |
| Benzoyl peroxide | | 5 | 0.01 | 0.13 | 0.023 | 0.30 |
| Diphenyl oxide | | 7 | 0.02 | 0.18 | 0.05 | 0.41 |
| Allyl alcohol | | 5 | 0.01 | 0.13 | 0.023 | 0.30 |

Table E-1. (Footnotes)

^aNIOSH and/or ACHIH have recommended lower standards for those chemicals denoted by an asterisk (*).

^bTWA = The time-weighted average concentration for up to an 8-hour work shift, 40-hour work week (NIOSH 1981).

^cThe standards for some of these chemicals are given only in parts per million (ppm). The corresponding concentrations in mg/m³ were calculated for air at 25°C and 760 millimeters of mercury.

^dThe OSHA standard for this chemical is a ceiling value (i.e., an employee's exposure to any substance with a ceiling value notation shall at no time exceed the value given in the table).

^eThe estimated PCB air concentration is based on the assumption that PCBs are present in the process stream and any emissions at 2 mg/kg, 25 mg/kg, or 50 mg/kg.

^fAnnual individual worker exposure assumes exposure to the estimated PCB concentration for 40 hours per week for 48 weeks per year. A breathing rate of 1.2 m³/hr, corresponding to the mean of the average breathing rates for medium activity and low activity stress levels (Versar 1982), was assumed. Exposure estimates assume that no protective clothing or respirators are worn by employees.

Table E-2. Estimated PCB Levels in Air Based on Compliance with OSHA Standards for Primary Chemicals
(Assuming that the regulated chemical is in air solely because of evaporation
and that the liquid chemical contains 50 mg/kg PCBs)

| Chemical ^a | Synonym | OSHA TWA standard ^{b,c} (mg/m ³) | Molecular weight | Vapor Pressure (torr) at 25°C | Maximum PCB air concentration expected ^e (ug/m ³) | Maximum annual individual PCB exposure ^g (mg/yr) |
|-----------------------------------|----------------------------|-------------------------------------------------------------|---------------------|----------------------------------|-----------------------------------------------------------------------------------|----------------------------------------------------------------------|
| Allyl chloride | 1-Chloro-2-propene | 3 | 76.53 | 400(27.5°C) | 1.5x10 ⁻⁷ | 3.5x10 ⁻⁷ |
| Aldrin | | 0.25 | 365 | 6.6x10 ⁻⁶ | f | f |
| Benzyl chloride | Alpha-chloro-toluene | 5 | 126.59 | 1(22°C) | 1.0x10 ⁻⁴ | 2.3x10 ⁻⁴ |
| Carbon tetrachloride | | 6.3 ^c | 153.82 | 113 | 1.1x10 ⁻⁶ | 2.6x10 ⁻⁶ |
| Chlordane | | 0.5 | 406 | 1x10 ⁻⁵ | f | f |
| Chlorinated camphene | Toxaphene | 0.5 | 414 | 0.2 | f | f |
| Chlorinated diphenyl oxide | Hexachlorodiphenyl oxide | 0.5 | 377 | <6x10 ⁻⁵ (20°C) | f | f |
| Chloroacetaldehyde | | 3 ^d | 78.5 | 100(20°C) | 6.0x10 ⁻⁷ | 1.4x10 ⁻⁶ |
| alpha-Chloroacetophenone | Chloromethyl phenyl ketone | 0.3 | 154.6 | 0.012(20°C) | f | f |
| Monochlorobenzene | | 350 | 112.56 | 12.5 | 5.6x10 ⁻⁴ | 1.3x10 ⁻³ |
| o-Chlorobenzylidene malononitrile | | 0.4 | 188.5 | <<1 | f | f |
| Chlorobromomethane | | 1,050 | 129.4 | 117(20°C) | 1.8x10 ⁻⁴ | 4.2x10 ⁻⁴ |
| *Chloroform | | 240 ^d | 119.38 | 200 | 2.4x10 ⁻⁵ | 5.5x10 ⁻⁵ |
| *1-Chloro-1-nitropropane | | 100 | 123.5 | 5.8(20°C) | 3.4x10 ⁻⁴ | 7.8x10 ⁻⁴ |
| Chloropicrin | Trichloronitromethane | 0.7 | 164.4 | 20(20°C) | 7.0x10 ⁻⁷ | 1.6x10 ⁻⁶ |
| *Chloroprene | 2-Chloro-1,3-butadiene | 90 | 88 | 179(20°C) | 1.0x10 ⁻⁵ | 2.3x10 ⁻⁵ |

Table E-2. (continued)

| Chemical ^a | Synonym | OSHA TWA standard ^{b,c} (mg/m ³) | Molecular weight | Vapor pressure (torr) at 25°C | Maximum PCB air concentration expected ^e (ug/m ³) | Maximum annual individual PCB exposure ^g (mg/yr) |
|------------------------------------|------------------------------------------|-------------------------------------------------------|------------------|-------------------------------|--------------------------------------------------------------------------|-------------------------------------------------------------|
| *Crag herbicide | Na-2-(2,4-dichlorophenoxy) ethyl sulfate | 15 | 309 | ~0 | f | f |
| 2,4-D | 2,4-Dichlorophenoxy acetic acid | 10 | 221 | ~0 | f | f |
| DDT | | 1 | 354.5 | 7.9x10 ⁻⁷ | f | f |
| DDVP | 2,2-Dichlorovinyl dimethyl phosphate | 1 | 221 | 0.032 (20°C) | 6.2x10 ⁻⁴ | 1.4x10 ⁻³ |
| o-Dichlorobenzene | | 300 ^d | 147.01 | 1.48 | 4.1x10 ⁻³ | 9.4x10 ⁻³ |
| p-Dichlorobenzene | | 450 | 147.01 | 1.79 | 5.0x10 ⁻³ | 1.2x10 ⁻² |
| Dichlorodifluoromethane | | 4,950 | 120.91 | 760 | 1.3x10 ⁻⁴ | 3.0x10 ⁻⁴ |
| 1,3-Dichloro-5,5-dimethylhydantoin | | 0.2 | 197 | NA | f | f |
| 1,1-Dichloroethane | Ethylidene chloride | 400 | 98.92 | 230 | 3.5x10 ⁻⁵ | 8.1x10 ⁻⁵ |
| 1,2-Dichloroethylene | | 790 | 96.95 | 180 (20°C) | 8.8x10 ⁻⁵ | 2.0x10 ⁻⁴ |
| *Dichloroethyl ether | Bis-2-(chloroethyl) ether | 90 ^d | 143 | 0.4 (20°C) | 4.5x10 ⁻³ | 1.0x10 ⁻² |
| *Dichlorofluoromethane | | 4,200 | 102.92 | 760 | 1.1x10 ⁻⁴ | 2.5x10 ⁻⁴ |
| *1,1-Dichloro-1-nitroethane | | 60 ^d | 144 | 15 (20°C) | 8.0x10 ⁻⁵ | 1.8x10 ⁻⁴ |
| Dichlorotetrafluoroethane | | 7,000 | 170.92 | 760 | 1.8x10 ⁻⁴ | 4.2x10 ⁻⁴ |
| Dieldrin | | 0.25 | 381 | 1.78x10 ⁻⁷ (20°C) | f | f |

Table E-2. (continued)

| Chemical ^a | Synonym | OSHA TWA standard ^{b,c} (mg/m ³) | Molecular weight | Vapor pressure (torr) at 25°C | Maximum PCB air concentration expected ^e (ug/m ³) | Maximum annual individual PCB exposure ^g (mg/yr) |
|------------------------|--------------------------------------------------|-------------------------------------------------------|------------------|-------------------------------|--------------------------------------------------------------------------|-------------------------------------------------------------|
| Dibrom | 1,2-Dibromo-2,2-dichloroethyl dimethyl phosphate | 3 | 381 | 2×10^{-4} (20°C) | f | f |
| Endrin | | 0.1 | 381 | 2×10^{-7} | f | f |
| *Epichlorohydrin | 1, -Chloro-2,3-epoxypropane | 19 | 92.53 | 13 (20°C) | 2.9×10^{-5} | 6.7×10^{-5} |
| Ethyl chloride | Monochloroethane | 2,600 | 64.47 | 760 | 6.8×10^{-5} | 1.6×10^{-4} |
| *Ethylene chlorohydrin | 2-Chloroethanol | 16 | 80.5 | 5 (20°C) | 1.6×10^{-3} | 3.7×10^{-3} |
| *Ethylene dichloride | 1,2-Dichloroethane | 200 ^c | 98.96 | 82 | 4.9×10^{-5} | 1.1×10^{-4} |
| Fluorotrichloromethane | | 5,600 | 137.4 | 760 | 1.5×10^{-4} | 3.4×10^{-4} |
| Heptachlor | | 0.5 | 373.5 | 3.0×10^{-4} | f | f |
| Hexachloroethane | | 10 | 236.74 | 0.21 (20°C) | f | f |
| Hexachlorocyclohexane | Lindane | 0.5 | 291 | 1.6×10^{-5} (20°C) | f | f |
| Hexachloronaphthalene | | 0.2 | 334.7 | NA | f | f |
| *Methoxychlor | 2,2-Bis(p-methoxyphenyl)-1,1,1-trichloroethane | 15 | 345.7 | NA | f | f |
| *Methyl chloride | Chloromethane | 200 ^c | 50.49 | 760 | 5.3×10^{-6} | 1.2×10^{-5} |
| Methyl chloroform | 1,1,1-Trichloroethane | 1,910 | 133.41 | 99 | 3.8×10^{-4} | 8.7×10^{-4} |

Table E-2. (continued)

| Chemical ^a | Synonym | OSHA TWA standard ^{b,c} (mg/m ³) | Molecular weight | Vapor pressure (torr) at 25°C | Maximum PCB air concentration expected ^e (ug/m ³) | Maximum annual individual PCB exposure ^g (mg/yr) |
|----------------------------------------|---------------------------------------------------------|-------------------------------------------------------|------------------|-------------------------------|--------------------------------------------------------------------------|-------------------------------------------------------------|
| *Methylene chloride | Dichloromethane | 1,740 | 84.92 | 438 | 7.9x10 ⁻⁵ | 1.8x10 ⁻⁴ |
| p-Nitrochlorobenzene | | 1 | 157.6 | <<1 | f | f |
| Octachloronaphthalene | | 0.1 | 403.7 | NA | f | f |
| *Paraquat | 1,1'-Dimethyl-4,4'-bipyridinium dichloride | 0.5 | 257.2 | ~0 | f | f |
| Pentachloronaphthalene | | 0.5 | 300.5 | NA | f | f |
| Pentachlorophenol | | 0.5 | 266.4 | 1.1x10 ⁻⁴ (20°C) | f | f |
| Perchloromethyl mercaptan | Trichloromethyl sulfur chloride | 0.8 | 185.9 | 65 (20°C) | 2.5x10 ⁻⁷ | 5.3x10 ⁻⁷ |
| Phosgene | Carbonyl chloride | 0.4 | 98.92 | 760 | 1.1x10 ⁻⁸ | 2.5x10 ⁻⁸ |
| Propylene dichloride | 1,2-Dichloropropane | 350 | 113 | 39.5 (20°C) | 1.8x10 ⁻⁴ | 4.1x10 ⁻⁴ |
| *Ronnel | 0,0-Dimethyl 0-(2,3,5-trichlorophenyl) phosphorothioate | 15 | 321.5 | 0.8x10 ⁻³ (20°C) | f | f |
| 2,4,5-T | 2,3,5-Trichlorophenoxy acetic acid | 10 | 255.5 | ~0 | f | f |
| 1,1,2,2-Tetrachloro-1,2-difluoroethane | | 4,170 | 203.83 | 40 (19.8°C) | 2.1x10 ⁻³ | 4.8x10 ⁻³ |
| 1,1,1,2-Tetrachloro-2,2-difluoroethane | | 4,170 | 203.83 | ~40 (20°C) | 2.1x10 ⁻³ | 4.8x10 ⁻³ |
| *1,1,2,2-Tetrachloroethane | | 35 | 167.85 | 8 (20°C) | 8.8x10 ⁻⁵ | 2.0x10 ⁻⁴ |

Table E-2. (continued)

| Chemical ^a | Synonym | OSHA TWA standard ^{b,c} (mg/m ³) | Molecular weight | Vapor pressure (torr) at 25°C | Maximum PCB air concentration exposure ^e (ug/m ³) | Maximum annual individual PCB exposure ^g (mg/yr) |
|---------------------------------------|---------|----------------------------------------------------------|------------------|-------------------------------|-----------------------------------------------------------------------------|----------------------------------------------------------------|
| *Tetrachloroethylene | | 680 ^c | 165.83 | 14 | 9.7x10 ⁻⁴ | 2.2x10 ⁻³ |
| Tetrachloronaphthalene | | 2 | 265.8 | NA | f | f |
| 1,1,2-Trichloroethane | | 45 | 133.41 | 18.8(20°C) | 4.8x10 ⁻⁵ | 1.1x10 ⁻⁴ |
| Trichloronaphthalene | | 5 | 231.4 | NA | f | f |
| 1,2,3-Trichloropropane | | 300 | 147.4 | 3.4(20°C) | 1.8x10 ⁻³ | 4.1x10 ⁻³ |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | | 7,600 | 187.38 | 284(20°C) | 5.4x10 ⁻⁴ | 1.2x10 ⁻³ |
| *Trichloroethylene | | 540 ^c | 131.39 | 59 | 1.8x10 ⁻⁴ | 4.1x10 ⁻⁴ |
| Vinyl Chloride | | 2.6 ^c | 62.5 | 760 | 6.8x10 ⁻⁸ | 1.6x10 ⁻⁷ |
| Ethylene diamine | | 25 | 60.11 | 10(21.5°C) | 5.0x10 ⁻⁵ | 1.2x10 ⁻⁴ |
| Propylene oxide | | 240 | 58.08 | 400(17.8°C) | 1.2x10 ⁻⁵ | 2.8x10 ⁻⁵ |
| Benzoyl peroxide | | 5 | 242.23 | <<1 | f | f |
| Diphenyl oxide | | 7 | 170.2 | <1 | 1.4x10 ⁻⁴ | 3.2x10 ⁻⁴ |
| Allyl alcohol | | 5 | 58.08 | 17.2(20°C) | 5.8x10 ⁻⁶ | 1.3x10 ⁻⁵ |

Table E-2. (Footnotes)

^aNIOSH and/or ACGIH have recommended lower standards for those chemicals denoted by an asterisk (*).

^bTWA = The time-weighted average concentration for up to an 8-hour work shift, 40-hour work week (NIOSH 1981).

^cThe standards for some of these chemicals are given only in parts per million (ppm). The corresponding concentrations in mg/m³ were calculated for air at 25°C and 760 millimeters of mercury.

^dThe OSHA standard for this chemical is a ceiling value (i.e., the standard is the permissible exposure limit at any time).

^eThe estimated maximum PCB air concentrations were calculated as follows:

$$\text{Max. PCB air concentration} = (A) \times \frac{(\text{OSHA limit for the chemical})}{(B)}$$

A = The maximum PCB air concentration at equilibrium above the liquid chemical.

B = The maximum air concentration of the chemical at equilibrium above the liquid chemical.

Both A and B were calculated determining the mole fraction of PCBs in solution and then using Raoult's Law and Dalton's Law of Partial Pressures as outlined in Attachment D. The air temperature was assumed to be 25°C. The molecular weight of PCBs was assumed to be 266.5 and the vapor pressure of PCBs was assumed to be 4×10^{-4} torr (i.e., the values for Aroclor 1242) (Hutzinger et al. 1974).

^fCalculations were not made for chemicals which are solids at 25°C.

^gAnnual individual worker exposure assumes exposure to the estimated PCB concentration for 40 hours per week for 48 weeks per year. A breathing rate of 1.2 m³/hr, corresponding to the mean of the average breathing rates for medium activity and low activity stress levels (Versar 1982), was assumed. Exposure estimates assume that no protective clothing or respirators are worn by employees.

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ATTACHMENT F

Hypothetical PCB Workplace Air Levels Associated with Airborne Particulate Matter Based on the OSHA Standard for Nuisance Dust

F.1. Introduction

The purpose of this attachment is to estimate maximum probable PCB levels in workplace air associated with airborne particulate matter that may contain incidentally produced PCBs. Examples of operations that may generate airborne particulate matter potentially contaminated with PCBs include

- Dusts generated during the loading/unloading/handling of powdered pigments.
- Dusts generated during production of newspapers printed with PCB-contaminated inks.
- Dusts generated during manufacture of garments dyed or printed with PCB-contaminated dyes/pigments.
- Paint mists generated during spray painting operations involving PCB-contaminated pigments or solvents.
- Dusts generated during the fabrication of plastic products manufactured with PCB-contaminated resins or pigments.

F.2. Estimation of PCB Air Concentrations and Worker Exposures

The current OSHA standard for nuisance dust is 15 mg/m^3 of total dust (5 mg/m^3 for the respirable portion of total dust) as an eight-hour, time-weighted average concentration (29 CFR 1910.1000). This standard is applicable for all inorganic or organic particulate matter in air for which no other more specific OSHA standards have been promulgated*.

*Personal communications between G. Schweer (Versar Inc.) and Marianne Garrahan (OSHA, Office of Field Coordination) and David Welsh (OSHA, Office of Standards Development) (February 1983).

Therefore, the maximum potential air concentration of PCBs associated with dust generated during the manufacturing, fabrication, or handling of a product of known PCB concentration can be estimated by assuming that the dust is present in the workplace air at the OSHA limit of 15 mg/m³ (5 mg/m³ for the respirable portion of the dust). This relationship is described in Equation F-1.

$$\text{PCB air concentration} = \text{PCB concentration in product/dust} \times \text{OSHA limit for nuisance dust} \quad (\text{F-1})$$

where, the PCB concentration in product/dust is expressed as a weight percentage.

Table F-1 lists the estimated PCB air concentrations and individual annual PCB exposures that may result for product PCB concentrations of 50 mg/kg, 25 mg/kg, and 2 mg/kg. Table F-2 lists actual concentrations of nuisance dusts that have been reported in various NIOSH studies.

Table F-1. Estimated PCB Air Concentrations and Individual Annual Exposures for PCBs Associated with Airborne Dust

| PCB concentration in product dust (mg/kg) | Estimated PCB air concentration ^a (ug/m ³) | | | Individual annual PCB exposure ^b (mg/yr) |
|-------------------------------------------------|-------------------------------------------------------------------|--------------------------------|---------------------------|-----------------------------------------------------|
| | For PCBs in total dust | For PCBs in respirable dust | For PCBs in total dust | |
| 2 | 0.03 | 0.01 | 0.069 | 0.023 |
| 25 | 0.38 | 0.13 | 0.88 | 0.30 |
| 50 | 0.75 | 0.25 | 1.7 | 0.58 |

^aPCB concentrations associated with particulate matter are calculated by multiplying the OSHA standard (i.e., 15 mg/m³ for total dust; 5 mg/m³ for respirable dust) by the PCB concentration in the product as a weight percentage (i.e., 2 mg/kg = 0.0002 percent).

^bAnnual individual worker exposure estimates assume exposure to the listed PCB concentration for 40 hours per week, 48 weeks per year at a breathing rate of 1.2 m³/hr (i.e., the mean of the average breathing rates for medium activity and low activity stress levels (Versar 1982)). Assuming compliance with the OSHA standard, no more than one-third of annual exposure to PCBs in total dust is respirable; however, the other two-thirds may become trapped in the nasopharynx and subsequently ingested. Exposure estimates assume that no respirators are worn.

Table F-2. Nuisance Dust Levels Measured in NIOSH Studies

| Occupational setting | Dust type | Nuisance dust levels (mg/m ³) | | Reference |
|----------------------|------------------|-------------------------------------------|---------|-------------|
| | | minimum | maximum | |
| Apparel manufacture | Garment lint | <0.1 | 1.8 | NIOSH 1974 |
| Apparel manufacture | Garment lint | 0.09 | 0.67 | NIOSH 1975 |
| Plastics finishing | Plastics | 0.16 | 0.17 | NIOSH 1976 |
| Plastics finishing | Plastics | 0.4 | 7.3 | NIOSH 1978a |
| Newspaper production | Paper dust | 0.3 | 4.7 | NIOSH 1979 |
| Loading/unloading | Pigments/resins | 0.26 | 9.27 | NIOSH 1978b |
| Loading/unloading | Pesticides | - | 1.6 | NIOSH 1977a |
| Loading/unloading | Chemical product | 5.9 | 7.7 | NIOSH 1977b |
| Loading/unloading | Chemical product | 0.3 | 0.5 | NIOSH 1977b |

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ATTACHMENT G

Hypothetical Worker Inhalation Exposure to PCBs During Manufacture of Plastic Products

G.1. Introduction

The purpose of this attachment is to estimate maximum probable worker inhalation exposure to PCBs potentially present in vapors released during the manufacture of plastic products. The manufacture of plastic products involves a variety of halogenated compounds whose manufacture has been determined to have a relatively high potential for incidentally producing PCBs*. For example, PCBs are known to be incidentally produced during the manufacture of vinyl chloride and may be present at low levels in polyvinyl chloride resins as a result. PCBs could also be present as contaminants in halogenated blowing agents, used in the manufacture of foamed plastic, and in additives such as pigments and flame retardants. In addition, certain chlorinated peroxide catalysts, used in the crosslinking or vulcanization of various thermoplastics and elastomers, can form PCBs as a side reaction during plastics manufacture (Meyer 1983).

Although PCBs are non-volatile at ambient temperatures (see Attachment D), the high temperatures involved in plastics manufacturing, often exceeding 150°C (Agranoff 1975), could result in some volatilization of PCBs. Air emissions from plastics manufacturing equipment are typically vented out of the workplace, but emission to workroom air can result from equipment leaks, mold openings and closings, and heat-cured plastic products during cooling. In addition, dusts generated during resin handling and during plastics fabrication operations (e.g., sanding, cutting, sawing) can be released to air; assessment of worker exposure to PCBs in plastics dust is addressed in Attachment F.

*Memorandum from Dr. S.J. Cristol (University of Colorado) to R. Westin (Versar Inc.) entitled "Organic Chemical Processes Leading to Generation of Incidental Polychlorinated Biphenyls" (dated February 10, 1983).

The following three sections present estimates of potential worker inhalation exposure to PCBs using three different scenarios. Section G.2 estimates potential PCB air levels during foamed plastics manufacture as a result of use of halogenated blowing agents. Section G.3 estimates potential air levels during manufacture of plasticized (i.e., flexible) plastic products. Section G.4 estimates potential air levels based on limited PCB monitoring data collected during manufacture of silicone rubber products when a chlorinated peroxide catalyst was used.

G.2. Estimation of PCB Air Levels and Annual Worker PCB Exposure During Manufacture of Foamed Plastics

G.2.1. Background

The manufacture of foamed plastics involves a wide variety of processes, formulations, and products, making the development of generic PCB exposure scenarios difficult. In addition, there is a lack of air monitoring data on which to base PCB exposure assessments. For these reasons, this exposure scenario will focus on potential occupational exposures to PCBs during manufacture of polyurethane foamed plastics. This product was selected because its manufacturing process commonly uses halogenated blowing agents and other additives that are potentially contaminated with PCBs. Also, the air concentration of a major constituent of the foam formulation is regulated by OSHA (i.e., toluene diisocyanate (TDI) vapors). The acceptable level of TDI (0.14 mg/m^3 as ceiling concentration limit) provides a basis for estimating air concentrations and hypothetical exposures to less volatile PCBs in the workplace.

G.2.2. Polyurethane Foam Manufacture

Polyurethane foam manufacturing operations typically involve reaction of an isocyanate, a polyol resin, and a blowing agent along with minor amounts of catalysts and additives to control the process (Suk and Skochdopole 1980). Approximately equal amounts of polyol and isocyanate

are reacted to produce rigid foams; approximately twice as much polyol is used to produce flexible foams (Meltzer 1971). Halogenated blowing agents may be used in proportions as high as 30 parts per hundred parts of resin (Agranoff 1975). Toluene diisocyanate is typically used as the isocyanate component of this process. TDI is highly toxic if inhaled and is regulated by OSHA to reduce potential for workplace exposure. TDI vapors must be kept below a ceiling concentration limit of 0.14 mg/m^3 at all times. TDI is usually added to the formulation at a rate in excess of 3 to 10 percent (Pigott 1970). This excess TDI is apparently the major source of TDI air emissions during the manufacturing operations (Sittig 1975).

Toluene diisocyanate vapors are heavier than air and tend to flow downward. For this reason, Lane (1974) recommends that ventilation around polyurethane foam processing equipment be at least 100 feet per minute; hoods over the top of the equipment should have air moving at sufficient velocity to ensure that the heavy TDI vapor is drawn away from workers. TDI has a vapor pressure of 5×10^{-2} torr at 25°C (NSC 1960), much higher than that for PCBs (4×10^{-4} for Aroclor 1242 at 25°C (Hutzinger et al. 1974)). The combination of high ventilation rates required to control TDI emissions and the lower vapor pressure of PCBs makes it likely that any inadvertent PCB vapors entering workplace air will be effectively removed.

G.2.3. General Assumptions

Estimates of hypothetical PCB concentrations in workplace air and hypothetical annual worker exposures to PCBs resulting from use of PCB-containing blowing agents are presented in Table G-1 based on the following assumptions:

- The blowing agent is being used at a level of 30 parts per hundred parts of polyol. The TDI is being used at 100 parts per hundred parts of polyol for rigid foams and at 50 parts per hundred parts for flexible foams.
- Five percent of the TDI in the formulation is excess TDI and is free to escape into air.

Table G-1. Estimated PCB Air Levels and Annual Individual Worker Exposure

| Product type | Estimated PCB air level ^a (mg/m ³) for PCB concentrations in blowing agent of | | | Annual individual worker exposure ^b (mg/yr) for PCB concentrations in blowing agent of: | | |
|----------------------------|---------------------------------------------------------------------------------------------------------|----------------------|----------------------|-------------------------------------------------------------------------------------------------------|-----------------|-----------------|
| | <u>2 mg/kg</u> | <u>25 mg/kg</u> | <u>50 mg/kg</u> | <u>2 mg/kg</u> | <u>25 mg/kg</u> | <u>50 mg/kg</u> |
| Polyurethane flexible foam | 3.4×10^{-6} | 4.2×10^{-5} | 8.4×10^{-5} | 0.0077 | 0.10 | 0.19 |
| Polyurethane rigid foam | 1.7×10^{-6} | 2.1×10^{-5} | 4.2×10^{-5} | 0.0039 | 0.048 | 0.10 |

^aCalculated using Equation G-1 and the assumptions listed in Section G.2.3.

^bCalculated assuming exposure to the estimated PCB concentration for 40 hours per week and 48 weeks per year, and using a breathing rate of 1.2 m³/hr (Versar 1982b). Exposure estimates assume no respirators are worn.

- TDI is present in workplace air at the OSHA limit (i.e., 0.14 mg/m³) and is maintained at that level by physical removal, such as ventilation, which removes a proportionate amount of PCBs*.
- PCBs are present in the blowing agent at concentrations of 50 mg/kg, 25 mg/kg, or 2 mg/kg.
- Despite the differences in their vapor pressures, it is assumed as a worst case, that all PCBs present in the blowing agent component of the foam formulation will be released to air at the same rate as the excess TDI.

Using the above assumptions, hypothetical PCB concentrations in air can be calculated using Equation G-1.

$$\text{PCB concentration in air} = \frac{\text{PCB concentration in blowing agent} \times \text{blowing agent use level}}{(\text{TDI use level}) \times (\% \text{ excess TDI})} \quad (\text{G-1})$$

× OSHA limit
for TDI

An example calculation for rigid foam is provided below.

$$\begin{aligned} \text{PCB conc. in air} &= \frac{(30 \text{ kg blowing agent}) \times (50 \text{ mg PCB/kg blowing agent}) \times (0.14 \text{ mg TDI/m}^3)}{(100 \text{ kg TDI}) \times (50,000 \text{ mg TDI/kg TDI})} \\ &= 4.2 \times 10^{-5} \text{ mg PCB/m}^3 \end{aligned}$$

*If TDI were replaced in the formulation by a less toxic isocyanate for which OSHA has set either no standards or a more lenient standard, and if the ventilation control requirements in the plant were relaxed to account for this change, then this hypothetical exposure scenario would be underestimating maximum probable PCB air levels and exposures.

G.3. Estimation of PCB Air Levels and Annual Worker PCB Exposure During Manufacture of Plasticized Plastic Products

G.3.1 Background

Maximum probable air levels of PCBs will be estimated in this section by extrapolation from the known maximum permissible level of a chemical of similar molecular weight and vapor pressure (di-n-butyl phthalate) which is used in plastics as a plasticizer.

Di-n-butyl phthalate is used as a plasticizer in various plastics, primarily in polyvinyl chloride (PVC) plastics (USEPA 1980). Phthalate esters are used in PVC at levels typically ranging from 20 percent to 60 percent by weight (Agranoff 1975, Versar 1982a). The current OSHA standard for di-n-butyl phthalate is 5 mg/m³ as an 8-hour time weighted average (29 CFR 1910.1000).

G.3.2 General Assumptions

It can be reasonably assumed, based on the following similarities, that approximately similar levels of PCBs and di-n-butyl phthalate would be found in workplace air if both chemicals were present at equal concentrations in a plastics formulation:

- The molecular weight of di-n-butyl phthalate is 278.3, and the molecular weight of Aroclor 1242 is 266.5 (USEPA 1981). Aroclor 1242 is a commercial mixture of primarily low molecular weight PCB isomers. PCB congeners containing 4 or fewer chlorines make up over 90% (by weight) of Aroclor 1242; the average number of chlorines per molecule is 3.1 (Hutzinger et al. 1974).
- The vapor pressure of di-n-butyl phthalate at 150°C is 1.1 torr (Agranoff 1975). The vapor pressure of Aroclor 1242 at 150°C is 3.3 torr (NAS 1979).
- Di-n-butyl phthalate, as a plasticizer, is not bound to the plastic matrix; rather, it is in solution throughout the plastic. Similarly, any PCBs present in the plastic resin would not be bound to the plastic matrix.

If it is further assumed that the ratio of PCB levels in air to di-n-butyl phthalate levels in air is roughly similar to the ratio of their levels in the plastic formulation, then maximum levels of PCBs in air can be estimated for various PCB concentrations in the plastic formulation assuming that the di-n-butyl phthalate level in air is 5 mg/m³ (i.e., the OSHA limit). This relationship is described in Equation G-2*.

$$\begin{array}{l} \text{(PCB level in air)} = \frac{\text{PCB concentration in plastic}}{\text{di-n-butyl phthalate concentration in plastic}} \times \frac{\text{di-n-butyl phthalate concentration in air}}{\text{di-n-butyl phthalate concentration in air}} \end{array} \quad (\text{G-2})$$

where

- The PCB concentration in plastic is calculated as follows:

$$\begin{array}{l} \text{PCB concentration in plastic} = \frac{\text{PCB concentration in feedstock}}{\text{weight fraction of feedstock to total plastic}} \end{array} \quad (\text{G-3})$$

- The di-n-butyl phthalate concentration in air is assumed to be 5 mg/m³ (i.e., the OSHA limit).
- The di-n-butyl phthalate concentration in the plastic is assumed to be 40 percent by weight (i.e., the midpoint of the range of use levels in PVC).

Table G-2 lists the estimated PCB levels in workplace air for various PCB concentrations in the plastic. These estimated levels were calculated using Equation G-2. Table G-2 also lists the potential annual PCB exposure for a worker exposed to those levels.

*If di-n-butyl phthalate were replaced in the formulation by a less volatile plasticizer with the same OSHA limit (e.g., di-2-ethylhexyl phthalate) and the ventilation control requirements in the plant were relaxed to account for this change, then this hypothetical exposure scenario would underestimate maximum probable PCB air levels and exposures.

Table G-2. Estimated PCB Air Concentrations and Worker Exposures

| PCB concentration in plastic ^a (mg/kg) | PCB concentration in workplace air ^b (mg/m ³) | Annual individual worker exposure ^c (mg/yr) |
|---------------------------------------------------------|----------------------------------------------------------------------------|--------------------------------------------------------------|
| 50 | 6.2×10^{-4} | 1.4 |
| 25 | 3.1×10^{-4} | 0.71 |
| 2 | 2.5×10^{-5} | 0.058 |

^aThese are assumed PCB concentrations in the plastic. Knowing the actual PCB concentration in a plastic feedstock, one can calculate an estimated PCB concentration in the formulated plastic using Eqn. G-3.

^bCalculated using Equation G-2.

^cCalculated assuming exposure to the listed concentrations for 40 hours per week, 48 weeks per year, at a breathing rate of 1.2 m³/hr (Versar 1982b).

G.4 Estimation of PCB Air Levels and Annual Worker PCB Exposure During Manufacturing of Silicon Rubber Products

Incidental manufacture of PCBs has been associated with the use of chlorinated benzoyl peroxide catalysts* in the curing (vulcanization) of silicone rubber. Silicone rubber processing always entails thermal cure (up to 24 hours at 250°C), and formulation always includes a catalyst. Chlorinated benzoyl peroxide catalysts are the most commonly used catalysts and may be used in the formulation at concentrations as high as 1.0 percent. The curing process involves the thermal decomposition of the peroxide catalyst into active free radical species which can react to form PCB isomers. The extent of this side reaction appears to range between 0.1 and 0.3 percent PCB from the catalyst (Meyer 1983).

Although manufacturing equipment is typically vented to the atmosphere, fugitive emissions into the workplace can occur. Measurements of PCB air levels inside one silicone rubber facility averaged $9 \mu\text{g}/\text{m}^3$ (Meyer 1983). If it is assumed that a worker is exposed to this air level 40 hours per week, 48 weeks per year and has an air intake rate of $1.2 \text{ m}^3/\text{hr}$, then the worker could have an annual PCB exposure of 21 mg/yr.

*The term catalyst as applied to organic peroxides is a misnomer because, unlike true catalysts, they decompose during the curing step and are not recoverable.

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ATTACHMENT H

Hypothetical Annual Exposure to PCBs via Ingestion of Food and Water Obtained from Water Bodies Located Downstream of Chemical Plants

H.1. Introduction

The purpose of this attachment is to estimate surface water concentrations of PCBs and subsequent human exposures that may result from discharge of industrial wastewater containing PCBs at a concentration of 100 ug/l (i.e., the LOQ for wastewater).

H.2. Estimation of Surface Water Concentrations

If it is assumed that PCBs are being discharged at a concentration of 100 ug/l, then the resulting surface water concentration can be estimated if "typical" stream dilution factors for organic chemical plant effluents are obtained. Using two of EPA's computerized data bases, the Industrial Facilities Discharge File* (IFD) and the GAGE File*, a frequency distribution of the stream dilution factors for the effluents of 348 plants in the following SIC codes was obtained:

- SIC 2821 (plastic material and resin manufacturers)
- SIC 2823 (cellulosic fiber manufacturers)
- SIC 2824 (non-cellulosic organic fiber manufacturers)
- SIC 2865 (cyclic crudes and intermediates manufacturers)
- SIC 2869 (organic chemical manufacturers, not elsewhere classified)

Table H-1 presents this frequency distribution of dilution factors and also lists the expected surface water concentrations of PCBs, assuming that the plants discharge process wastewater containing 100 ug/l of PCBs.

*The IFD and GAGE Files were developed and are maintained by EPA's Office of Water Regulations and Standards.

Table H-1. Estimated PCB Surface Water Concentrations
Downstream of Organic Chemical Plants

| Percentile ^a | Stream dilution factors ^b | | PCB surface water concentration ^c (ug/l) | |
|-------------------------|--------------------------------------|----------------|-----------------------------------------------------|----------------|
| | Average streamflow | Low streamflow | Average streamflow | Low streamflow |
| 10 | 58.2 | 1.52 | 1.7 | 66 |
| 20 | 214 | 6.36 | 0.47 | 16 |
| 30 | 522 | 18.9 | 0.19 | 5.3 |
| 40 | 1,130 | 56.1 | 0.088 | 1.8 |
| 50 | 2,620 | 179 | 0.038 | 0.56 |
| 60 | 5,630 | 476 | 0.018 | 0.21 |
| 70 | 15,300 | 1,780 | 0.0065 | 0.056 |
| 80 | 63,700 | 6,270 | 0.0016 | 0.016 |
| 90 | 270,000 | 40,000 | 0.00037 | 0.0025 |

^aPercentile refers to the percent of plants with stream dilution factors less than or equal to the stated value. For example, 20 percent of the 348 plants upon which this frequency distribution is based have stream dilution factors of 214 or less at average streamflow and 6.36 or less at low streamflow.

^bAll data obtained from EPA's IFD/GAGE File (see Section H.2. for details).

^cAssuming that all plants discharge process wastewater containing 100 ug/l of PCBs, the PCB surface water concentrations were calculated by dividing 100 ug/l by the respective dilution factor.

H.3. Estimation of Annual PCB Exposures

Using the estimated PCB surface water concentrations listed in Table H-1, annual PCB exposures for a person ingesting 2 liters of water per day were calculated. These estimated annual exposures are listed in Table H-2. Table H-2 also lists the estimated annual exposures for a person ingesting fish/shellfish from these waters using the following assumptions:

- The average bioconcentration factor of PCBs in fish/shellfish is 31,200 (USEPA 1980).
- The estimated average per capita consumption of fish/shellfish in the United States is 6.5 grams per day (USEPA 1980).

The estimated annual exposures listed in Table H-2 can be compared to the average dietary intake of PCBs, estimated using the following information and scenarios:

- The average adult intake of PCBs via food during 1978 has been estimated by FDA (FDA 1981) to be 0.027 ug/kg/day or approximately 0.69 mg per year for a 70 kg individual.
- Ingestion of 6.5 g of fish per day containing 2 ppm of PCBs (i.e., the 1977 proposed FDA tolerance level for PCBs in the edible portion of fish*) will result in an annual exposure of 4.75 mg.
- Ingestion of 2 liters of water and 6.5g of fish per day from a water body containing 0.079 ng/l of PCBs (i.e., the USEPA Ambient Water Quality Criterion for the Protection of Human Health at the 10^{-6} risk level) (USEPA 1980) will result in an annual exposure of 0.006 mg.

*Personal communication between G. Schweer (Versar Inc.) and Sonia Delgado (FDA, Division of Regulatory Guidance) (February 1983).

Table H-2. Estimated Annual Individual PCB Exposures

| PCB surface water concentration ^a (ug/l) | Estimated Annual Individual PCB Exposure (mg/yr) | |
|-----------------------------------------------------|--------------------------------------------------|-------------------------------------|
| | Ingestion of water only ^b | Ingestion of fish only ^c |
| Avg. streamflow | Avg. streamflow | Avg. streamflow |
| 1.7 | 1.2 | 130 |
| 0.47 | 0.34 | 35 |
| 0.19 | 0.14 | 14 |
| 0.088 | 0.064 | 6.5 |
| 0.038 | 0.028 | 2.8 |
| 0.018 | 0.013 | 1.3 |
| 0.0065 | 0.0047 | 0.48 |
| 0.0016 | 0.0012 | 0.12 |
| 0.00037 | 0.00027 | 0.027 |

^aSource: Table H-1

^bCalculated as follows:

$$\text{Annual PCB exposure} = (2 \text{ liters/day}) \times (365 \text{ days/yr}) \times (\text{PCB concentration})$$

^cCalculated as follows (see Section H.3 for assumptions):

$$\text{Annual PCB exposure} = (0.0065 \text{ kg/day}) \times (31,200 \text{ BCF}) \times (365 \text{ days/yr}) \times (\text{PCB concentration})$$

where, BCF is expressed in terms of $\frac{(\text{mass of PCBs/kg of fish})}{(\text{mass of PCBs/l of water})}$

References

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ATTACHMENT I

Hypothetical Annual Exposure to PCBs via Ingestion of Water Obtained from Water Bodies Located Downstream of Industries Using Chemicals Potentially Containing PCBs

I.1 Introduction

PCBs are known or are suspected to be incidentally generated during the manufacture of highly chlorinated, short chain aliphatic compounds such as methyl chloroform, carbon tetrachloride, perchloroethylene, and trichloroethylene. If these chemicals contain low levels of PCBs when sold to user industries, then the potential exists for discharge of PCBs if these host chemicals are discharged in wastewater by the user industries.

The purpose of this attachment is to estimate surface water concentrations of various congeners of PCBs and subsequent human exposures that may result from the use and discharge of chemicals potentially containing incidentally produced PCBs. The four chemicals mentioned in the paragraph above will be used as example host chemicals in this attachment.

I.2 Basic Assumptions

In order to estimate potential surface water concentrations of PCBs, the following five basic assumptions are made:

- An industrial effluent containing a host chemical at its solubility limit (25°C) is discharged into a river.
- The effluent is diluted by a factor of either 461 or 11 by the receiving stream. These are the dilution factors reported for 50 percent and 10 percent, respectively, of all industrial and POTW effluents in the United States under mean stream flow conditions (GSC 1982).
- PCBs are originally present in the discharged chemical (i.e., relative to the chemical, not the entire effluent) at a concentration of 50 mg/kg.

- A drinking water intake is located downstream at the point where the in-stream concentration of the chemical under typical conditions becomes undetectable. According to Versar (1982), most drinking water supplies contain less than detectable levels of the examined chemicals (over 90% of U.S. population is served by water containing less than 0.5 ug/l of perchloroethylene, trichloroethylene, and methyl chloroform; over 82% are served by water with less than 0.5 ug/l carbon tetrachloride).
- The only process affecting removal of the chemical and PCBs from water is volatilization. The chemicals examined do not undergo any significant degree of biodegradation, hydrolysis, oxidation, or photolysis in waters. Nor are they expected to undergo any significant degree of bioaccumulation or sorption to sediments (USEPA 1979). PCBs do not undergo any significant degree of hydrolysis or oxidation. Only highly chlorinated biphenyls undergo any significant degree of photolysis in solution. Only biphenyls of low chlorine content (i.e., tetrachloro or less) appear to undergo any significant degree of biodegradation, and these rates are on the order of days to weeks whereas for the same molecules, the rates of volatilization are on the order of hours to days (USEPA 1983). Although PCBs will strongly sorb to sediments and suspended organic matter, it is assumed, as a worst case, that all PCBs remain in solution or volatilize.

I.3 Estimation of Surface Water Concentrations and Potential Human Exposures

Given the basic assumptions listed in Section I.2, the following four steps are required to estimate potential PCB water concentrations:

- Step 1: Estimate the volatilization rate constants of the four host chemicals from water.
- Step 2: Estimate the initial concentrations of the host chemicals in water and the time required for their concentrations to decrease to non-detectable levels.
- Step 3: Estimate the volatilization rate constants for the PCB congeners examined (i.e., mono-, di-, tri-, tetra-, and pentachlorobiphenyls) from water.
- Step 4: Estimate the initial concentrations of the PCB congeners in water and their concentrations after the time required for the host chemical concentrations to decrease to non-detectable levels.

Table I-1 lists the results of Step 1. The volatilization rate constants were estimated using the recommended method of Lyman et al. (1982). The data required to calculate volatilization rates using this method are listed in the table.

Table I-2 lists the results of Step 2 for two stream flow dilution factors. The dilution factor of 461 is the median dilution factor for all industrial and POTW effluents in the United States; the dilution factor of 11 is the dilution factor for 10 percent of the industrial and POTW effluents (GSC 1982). The time required for the host chemical concentration to decrease to non-detectable levels was estimated assuming first-order rate kinetics for the volatilization of the host chemicals from water.

Tables I-3 through I-6 list the results of Steps 3 and 4. Volatilization rate constants are listed in the tables for mono-, di-, tri-, tetra-, and pentachlorobiphenyls. These constants are the means of the constants for various isomers in the listed congener groups as estimated in USEPA (1983) using the recommended method of Lyman et al. (1982) and assuming the same temperature, river depth, river speed, and wind velocity as were used to calculate the volatilization rate constants for the host chemicals listed in Table I-1. The constants were calculated using measured water solubility values and both measured and estimated vapor pressure values. The steps involved in calculating the final PCB water concentrations and potential annual individual drinking water exposures are explained in the footnotes to the tables.

Table I-1. Estimated Volatilization Rate Constants of Host Chemicals

| Chemical | Solubility ^a (mg/l) | (mol/m ³) | Vapor pressure ^b (atm) | Henry's law constant ^c (atm-m ³ /mol) | Mass transfer coefficient ^d K_L (m/hr) | Volatilization rate constant ^e k_v (hr ⁻¹) |
|----------------------|-----------------------------------|-----------------------|-----------------------------------------|-------------------------------------------------------------------|-----------------------------------------------------------|---------------------------------------------------------------------------|
| Methyl chloroform | 730 | 5.5 | 1.3×10^{-1} | 2.4×10^{-2} | 20.2 | 0.202 |
| Carbon tetrachloride | 800 | 5.2 | 1.5×10^{-1} | 2.9×10^{-2} | 18.9 | 0.189 |
| Perchloroethylene | 200 | 1.2 | 1.8×10^{-2} | 1.5×10^{-2} | 18.0 | 0.180 |
| Trichloroethylene | 1100 | 8.4 | 7.8×10^{-2} | 9.3×10^{-3} | 20.0 | 0.200 |

^aWater solubility at 25°C (Thibodeaux 1979, USEPA 1981).

^bVapor pressure at 25°C (Thibodeaux 1979).

^cEstimated Henry's law constant at 25°C.

^dEstimated liquid-phase mass transfer coefficients at 25°C by the recommended method of Lyman et al. (1982). The estimated coefficients correspond to a 100 cm deep river flowing at a speed of 100 cm/second and a wind velocity of 300 cm/second.

^e $k_v = K_L/Z$ where Z = river depth (100 cm).

Table I-2. Estimated Host Chemical Concentrations in Water

| Chemical | Volatilization rate constant ^a k_v (hr ⁻¹) | Initial conc. ^b C_0 (ug/l) | Final conc ^c C_T (ug/l) | Time required ^d T (hrs) | % C_0 remaining after T hrse |
|-------------------------------------------------|---------------------------------------------------------------------------|-----------------------------------------------|--------------------------------------------|--------------------------------------------|-------------------------------------|
| <u>Assuming a stream dilution factor of 461</u> | | | | | |
| Methyl chloroform | 0.202 | 1,600 | 0.5 | 40 | 3.1×10^{-2} |
| Carbon tetrachloride | 0.189 | 1,700 | 0.5 | 43 | 2.9×10^{-2} |
| Perchloroethylene | 0.180 | 430 | 0.5 | 38 | 1.2×10^{-1} |
| Trichloroethylene | 0.200 | 2,400 | 0.5 | 42 | 2.1×10^{-2} |
| <u>Assuming a stream dilution factor of 11</u> | | | | | |
| Methyl chloroform | 0.202 | 66,000 | 0.5 | 58 | 7.6×10^{-4} |
| Carbon tetrachloride | 0.189 | 73,000 | 0.5 | 63 | 6.8×10^{-4} |
| Perchloroethylene | 0.180 | 18,000 | 0.5 | 58 | 2.8×10^{-3} |
| Trichloroethylene | 0.200 | 100,000 | 0.5 | 61 | 5.0×10^{-4} |

^aSee Table I-1 for source.^bAs a worst case, it is assumed that an industrial effluent containing the chemical at its solubility limit (25°C) is discharged into the river. The effluent is assumed to be diluted by a factor of 461 or 11 for the river (see Section I-2 for details). Thus, the initial concentration was calculated by dividing the solubility of the chemical by either 461 or 11.^cVersar (1982) reports that the drinking water ingested by over 90 percent of the U.S. population contains non-detectable levels (i.e., < 0.5 ug/l) of methyl chloroform, perchloroethylene, and trichloroethylene. Carbon tetrachloride is present at non-detectable levels in waters ingested by over 82 percent of the population.^dCalculated as follows:
$$T = \frac{\ln C_T - \ln C_0}{-K_v}$$
^eCalculated as follows:
$$\frac{C_T}{C_0} \times 100\%$$

Table I-3. Estimated PCB Drinking Water Concentrations and Exposures Associated with Methyl Chloroform

| PCB congener | Volatilization rate constant ^a k_v (hr ⁻¹) | Initial PCB concentration ^b C_0 (ug/l) | % of C_0 remaining after ___ hrs ^c | Ratio of % of C_0 remaining to % of host chemical remaining after ___ hrs ^d | Estimated PCB drinking water concentration ^e (ug/l) | Estimated annual individual exposure ^f (mg/yr) |
|-------------------------------------------------|---------------------------------------------------------------------------|-----------------------------------------------------------|-------------------------------------------------------|------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|-----------------------------------------------------------------|
| <u>Assuming a stream dilution factor of 461</u> | | | | | | |
| Monochlorobiphenyl | 0.15 | 7.9×10^{-2} | 2.5×10^{-1} | 8.1 | 2.0×10^{-4} | 1.5×10^{-4} |
| Dichlorobiphenyl | 0.14 | 7.9×10^{-2} | 3.7×10^{-1} | 12 | 3.0×10^{-4} | 2.2×10^{-4} |
| Trichlorobiphenyl | 0.061 | 7.9×10^{-2} | 8.7 | 2.8×10^2 | 7.0×10^{-3} | 5.1×10^{-3} |
| Tetrachlorobiphenyl | 0.049 | 7.9×10^{-2} | 14 | 4.5×10^2 | 1.1×10^{-2} | 8.0×10^{-3} |
| Pentachlorobiphenyl | 0.036 | 7.9×10^{-2} | 24 | 7.7×10^2 | 1.9×10^{-2} | 1.4×10^{-2} |
| <u>Assuming a stream dilution factor of 11</u> | | | | | | |
| Monochlorobiphenyl | 0.15 | 3.3 | 1.7×10^{-2} | 22 | 5.5×10^{-4} | 4.0×10^{-4} |
| Dichlorobiphenyl | 0.14 | 3.3 | 3.0×10^{-2} | 39 | 9.8×10^{-4} | 7.2×10^{-4} |
| Trichlorobiphenyl | 0.061 | 3.3 | 2.9 | 3.8×10^3 | 9.5×10^{-2} | 6.9×10^{-2} |
| Tetrachlorobiphenyl | 0.049 | 3.3 | 5.8 | 7.6×10^3 | 1.9×10^{-1} | 1.4×10^{-1} |
| Pentachlorobiphenyl | 0.036 | 3.3 | 12 | 1.6×10^4 | 4.0×10^{-1} | 2.9×10^{-1} |

CC
OT

Table I-3. (Footnotes)

^aSource: USEPA 1983.

^bCalculated as follows: $\frac{\text{solubility of host chemical (ug/l)}}{\text{dilution factor}} \times \frac{50 \times 10^{-6} \text{ kg PCB}}{\text{kg host chemical}}$

^cAs shown in Table I-2, the time required for the initial concentration of methyl chloroform to be reduced to 0.5 ug/l is 40 hrs assuming a stream dilution factor of 461, and 58 hrs assuming a stream dilution factor of 11. The percent of any initial PCB concentration remaining after 40 or 58 hrs is calculated as follows:

$$\% \text{ remaining} = (100\%) (e^{-K_p})(_ \text{hrs})$$

^dPercent of initial chemical concentration remaining after 40 and 58 hrs was calculated in Table I-2.

^eCalculated as follows assuming PCBs were initially present in the chemical at 50 mg/kg:

$$\text{PCB conc.} = \frac{0.5 \text{ ug of chemical}}{1 \text{ liter}} \times \frac{50 \times 10^{-6} \text{ kg of PCBs}}{\text{kg of chemical}} \times (\text{ratio listed in column 4})$$

^fCalculated assuming ingestion of 2 liters of water daily, 365 days per year and assuming no removal during drinking water treatment.

Table I-4. Estimated PCB Drinking Water Concentrations and Exposures Associated with Carbon Tetrachloride

| PCB congener | Volatilization rate constant ^a k_v (hr ⁻¹) | Initial PCB concentration ^b C_0 (ug/l) | % of C_0 remaining after ___ hrs ^c | Ratio of % of C_0 remaining to % of host chemical remaining after ___ hrs ^d | Estimated PCB drinking water concentration ^e (ug/l) | Estimated annual individual exposure ^f (mg/yr) |
|-------------------------------------------------|---------------------------------------------------------------------------|-----------------------------------------------------------|-------------------------------------------------------|------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|-----------------------------------------------------------------|
| <u>Assuming a stream dilution factor of 461</u> | | | | | | |
| Monochlorobiphenyl | 0.15 | 8.7×10^{-2} | 1.6×10^{-1} | 5.5 | 1.4×10^{-4} | 1.0×10^{-4} |
| Dichlorobiphenyl | 0.14 | 8.7×10^{-2} | 2.4×10^{-1} | 8.3 | 2.1×10^{-4} | 1.5×10^{-4} |
| Trichlorobiphenyl | 0.061 | 8.7×10^{-2} | 7.3 | 2.5×10^2 | 6.2×10^{-3} | 4.5×10^{-3} |
| Tetrachlorobiphenyl | 0.049 | 8.7×10^{-2} | 12 | 4.1×10^2 | 1.0×10^{-2} | 7.3×10^{-3} |
| Pentachlorobiphenyl | 0.036 | 8.7×10^{-2} | 21 | 7.2×10^2 | 1.8×10^{-2} | 1.3×10^{-2} |
| <u>Assuming a stream dilution factor of 11</u> | | | | | | |
| Monochlorobiphenyl | 0.15 | 3.6 | 7.9×10^{-3} | 12 | 3.0×10^{-4} | 2.2×10^{-4} |
| Dichlorobiphenyl | 0.14 | 3.6 | 1.5×10^{-2} | 22 | 5.5×10^{-4} | 4.0×10^{-4} |
| Trichlorobiphenyl | 0.061 | 3.6 | 2.1 | 3.1×10^3 | 7.8×10^{-2} | 5.7×10^{-2} |
| Tetrachlorobiphenyl | 0.049 | 3.6 | 4.6 | 6.8×10^3 | 1.7×10^{-1} | 1.2×10^{-1} |
| Pentachlorobiphenyl | 0.036 | 3.6 | 10 | 1.5×10^4 | 3.8×10^{-1} | 2.8×10^{-1} |

Table I-4. (Footnotes)

^aSource: USEPA 1983.

^bCalculated as follows:
$$\frac{\text{solubility of host chemical (ug/l)}}{\text{dilution factor}} \times \frac{50 \times 10^{-6} \text{ kg PCB}}{\text{kg host chemical}}$$

^cAs shown in Table I-2, the time required for the initial concentration of carbon tetrachloride to be reduced to 0.5 ug/l is 43 hrs assuming a stream dilution factor of 461, and 63 hrs assuming a stream dilution factor of 11. The percent of any initial PCB concentration remaining after 43 or 63 hrs is calculated as follows:

$$\% \text{ remaining} = (100\%) (e^{-K_d})(_hrs)$$

^dPercent of initial chemical concentration remaining after 43 and 63 hrs was calculated in Table I-2.

^eCalculated as follows assuming PCBs were initially present in the chemical at 50 mg/kg:

$$\infty \quad \text{PCB conc.} = \frac{0.5 \text{ ug of chemical}}{\text{liter}} \times \frac{50 \times 10^{-6} \text{ kg of PCBs}}{\text{kg of chemical}} \times (\text{ratio listed in column 4})$$

^fCalculated assuming ingestion of 2 liters of water daily, 365 days per year and assuming no removal during drinking water treatment.

Table I-5. Estimated PCB Drinking Water Concentrations and Exposures Associated with Perchloroethylene

| PCB congener | Volatilization rate constant ^a k_v (hr^{-1}) | Initial PCB concentration ^b C_0 ($\mu g/l$) | % of C_0 remaining after ___ hrs ^c | Ratio of % of C_0 remaining to % of host chemical remaining after ___ hrs ^d | Estimated PCB drinking water concentrations ^e ($\mu g/l$) | Estimated annual individual exposure ^f (mg/yr) |
|-------------------------------------------------|---------------------------------------------------------------------|------------------------------------------------------------------|-------------------------------------------------------|------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------|
| <u>Assuming a stream dilution factor of 461</u> | | | | | | |
| Monochlorobiphenyl | 0.15 | 2.2×10^{-2} | 3.3×10^{-1} | 2.8 | 7.0×10^{-5} | 5.1×10^{-5} |
| Dichlorobiphenyl | 0.14 | 2.2×10^{-2} | 4.9×10^{-1} | 4.1 | 1.0×10^{-4} | 7.3×10^{-5} |
| Trichlorobiphenyl | 0.061 | 2.2×10^{-2} | 9.8 | 82 | 2.0×10^{-3} | 1.5×10^{-3} |
| Tetrachlorobiphenyl | 0.049 | 2.2×10^{-2} | 16 | 1.3×10^2 | 3.2×10^{-3} | 2.3×10^{-3} |
| Pentachlorobiphenyl | 0.036 | 2.2×10^{-2} | 25 | 2.1×10^2 | 5.2×10^{-3} | 3.8×10^{-3} |
| <u>Assuming a stream dilution factor of 11</u> | | | | | | |
| Monochlorobiphenyl | 0.15 | 9.1×10^{-1} | 1.7×10^{-2} | 6.1 | 1.5×10^{-4} | 1.1×10^{-4} |
| Dichlorobiphenyl | 0.14 | 9.1×10^{-1} | 3.0×10^{-2} | 11 | 2.8×10^{-4} | 2.0×10^{-4} |
| Trichlorobiphenyl | 0.061 | 9.1×10^{-1} | 2.9 | 1.0×10^3 | 2.5×10^{-2} | 1.8×10^{-2} |
| Tetrachlorobiphenyl | 0.049 | 9.1×10^{-1} | 5.8 | 2.1×10^3 | 5.2×10^{-1} | 3.8×10^{-2} |
| Pentachlorobiphenyl | 0.036 | 9.1×10^{-1} | 12 | 4.3×10^3 | 1.1×10^{-1} | 8.0×10^{-2} |

Table I-5. (Footnotes)

^aSource: USEPA 1983.

^bCalculated as follows: $\frac{\text{solubility of host chemical (ug/l)}}{\text{dilution factor}} \times \frac{50 \times 10^{-6} \text{ kg PCB}}{\text{kg host chemical}}$

^cAs shown in Table I-2, the time required for the initial concentration of perchloroethylene to be reduced to 0.5 ug/l is 38 hrs assuming a stream dilution factor of 461, and 58 hrs assuming a stream dilution factor of 11. The percent of any initial PCB concentration remaining after 38 or 58 hrs is calculated as follows:

$$\% \text{ remaining} = (100\%) (e^{-K_d})(_ \text{hrs})$$

^dPercent of initial chemical concentration remaining after 38 and 58 hrs was calculated in Table I-2.

^eCalculated as follows assuming PCBs were initially present in the chemical at 50 mg/kg:

$$\text{PCB conc.} = \frac{0.5 \text{ ug of chemical}}{\text{liter}} \times \frac{50 \times 10^{-6} \text{ kg of PCBs}}{\text{kg of chemical}} \times (\text{ratio listed in column 4})$$

^fCalculated assuming ingestion of 2 liters of water daily, 365 days per year and assuming no removal during drinking water treatment.

Table I-6. Estimated PCB Drinking Water Concentrations and Exposures Associated with Trichloroethylene

| PCB congener | Volatilization rate constant ^a k_v (hr^{-1}) | Initial PCB concentration ^b C_0 ($\mu g/l$) | % of C_0 remaining after ___ hrs ^c | Ratio of % of C_0 remaining to % of host chemical remaining after ___ hrs ^d | Estimated PCB drinking water concentrations ^e ($\mu g/l$) | Estimated annual individual exposure ^f (mg/yr) |
|-------------------------------------------------|---------------------------------------------------------------------|------------------------------------------------------------------|-------------------------------------------------------|------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|-----------------------------------------------------------------|
| <u>Assuming a stream dilution factor of 461</u> | | | | | | |
| Monochlorobiphenyl | 0.15 | 1.2×10^{-2} | 1.8×10^{-1} | 8.6 | 2.2×10^{-4} | 1.6×10^{-4} |
| Dichlorobiphenyl | 0.14 | 1.2×10^{-2} | 2.8×10^{-1} | 13 | 3.2×10^{-4} | 2.3×10^{-4} |
| Trichlorobiphenyl | 0.061 | 1.2×10^{-2} | 7.7 | 3.7×10^2 | 9.2×10^{-3} | 6.7×10^{-3} |
| Tetrachlorobiphenyl | 0.049 | 1.2×10^{-2} | 13 | 6.2×10^2 | 1.6×10^{-2} | 1.2×10^{-2} |
| Pentachlorobiphenyl | 0.036 | 1.2×10^{-2} | 22 | 1.0×10^3 | 2.5×10^{-2} | 1.8×10^{-2} |
| <u>Assuming a stream dilution factor of 11</u> | | | | | | |
| Monochlorobiphenyl | 0.15 | 5.0 | 1.1×10^{-2} | 22 | 5.5×10^{-4} | 4.0×10^{-4} |
| Dichlorobiphenyl | 0.14 | 5.0 | 2.0×10^{-2} | 40 | 1.0×10^{-3} | 7.3×10^{-4} |
| Trichlorobiphenyl | 0.061 | 5.0 | 2.4 | 4.8×10^3 | 1.2×10^{-1} | 8.8×10^{-2} |
| Tetrachlorobiphenyl | 0.049 | 5.0 | 5.0 | 1.0×10^4 | 2.5×10^{-1} | 1.8×10^{-1} |
| Pentachlorobiphenyl | 0.036 | 5.0 | 11 | 2.2×10^4 | 5.5×10^{-1} | 4.0×10^{-1} |

Table I-6. (Footnotes)

^aSource: USEPA 1983.

^bCalculated as follows: $\frac{\text{solubility of host chemical (ug/l)}}{\text{dilution factor}} \times \frac{50 \times 10^{-6} \text{ kg PCB}}{\text{kg host chemical}}$

^cAs shown in Table I-2, the time required for the initial concentration of trichloroethylene to be reduced to 0.5 ug/l is 42 hrs assuming a stream dilution factor of 461, and 61 hrs assuming a stream dilution factor of 11. The percent of any initial PCB concentration remaining after 42 or 61 hrs is calculated as follows:

$$\% \text{ remaining} = (100\%) (e^{-K_d})(_ \text{hrs})$$

^dPercent of initial chemical concentration remaining after 42 and 61 hrs were calculated in Table I-2.

^eCalculated as follows assuming PCBs were initially present in the chemical at 50 mg/kg:

$$\text{PCB conc.} = \frac{0.5 \text{ ug of chemical}}{\text{liter}} \times \frac{50 \times 10^{-6} \text{ kg of PCBs}}{\text{kg of chemical}} \times (\text{ratio listed in column 4})$$

^fCalculated assuming ingestion of 2 liters of water daily, 365 days per year and assuming no removal during drinking water treatment.

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ATTACHMENT J

Hypothetical Worker Inhalation Exposure to PCBs During Grain Fumigation

J.1. Introduction

The purpose of this attachment is to estimate maximum probable inhalation exposure to workers treating stored grain with liquid fumigants that may be contaminated with PCBs.

Grain fumigant formulations commonly are or have been comprised of mixtures of chlorinated methanes, ethanes, and ethylenes such as chloroform, carbon tetrachloride, ethylene dichloride, trichloroethylene, and perchloroethylene. Of these chlorinated chemicals, only ethylene dichloride, carbon tetrachloride, and chloroform are currently registered for use on stored grain.*

J.2. Estimation of PCB Concentration in Grain Fumigants

The concentration of PCBs in a formulated grain fumigant depends on the concentration of PCBs in the specific ingredient, as well as the concentration of that ingredient in the formulation. The most widely used fumigant containing carbon tetrachloride is a mixture known as 80/20, which consists of about 80% carbon tetrachloride and about 20% carbon disulfide by weight. In this fumigant, any PCBs in the carbon tetrachloride would be diluted by the CS_2 . This product is used on all kinds of grain stored in bins and boxcars, at typical rates of 4 to 8 gallons per thousand bushels, depending on type of grain, type of enclosure, grain moisture content, and ambient temperature (Hopes Consulting 1980).

Another commonly used formulation is a 3:1 mixture of ethylene dichloride and carbon tetrachloride. This mixture could have a high PCB concentration, since both of its components may contain incidentally produced PCBs. Either the 3:1 formulation or 80/20 may also contain approximately 6% ethylene dibromide (EDB).

*Personal communication between J. Doria (Versar) and D. Peacock (U.S.EPA, Office of Pesticide Programs), April 25, 1983.

Chloroform is used in only one registered grain fumigant, Vulcan's Clorofume, at a little over 70% by weight. The rest of the formulation is mostly CS₂, with about 7% EDB. Use of this product is insignificant compared with other grain fumigants (USEPA 1982).

J.3. Estimation of Hypothetical Exposure to PCBs

Grain fumigants are classified as restricted pesticides by EPA. Individuals who plan to use or supervise the use of restricted pesticides are required to demonstrate that they possess a practicable knowledge of pest problems and pest control practices, and such knowledge must be verified by a responsible State agency through the administration of an approved applicators certification system (Storey et al. 1979).

Liquid fumigants exert their effect in the vapor phase by asphyxiating the pest organisms. Although these compounds are heavier than air, it is essential to deliver the fumigant into the grain mass for vaporization within the grain mass rather than into the air space above the grain. Consequently, all instructions for use direct that a very coarse spray or stream (at ambient temperature) be applied directly to the surface of the grain mass (Hopes Consulting 1980). This may be accomplished with standard spray equipment, provided the nozzle is replaced by a section of quarter-inch pipe flattened on the delivery end (Storey et al. 1979). In farm storage bins and elevators, the fumigant is applied by a worker who is physically outside the bin, and who is directed (both by label instructions and OSHA recommendations) to wear either a full-face gas mask with appropriate canister or a supplied-air respiratory protective device (Hopes Consulting 1980).

Only in the case of flat storage (i.e., a horizontally oriented structure as opposed to a vertically oriented structure such as a grain elevator) is the applicator likely to be within the enclosure. Here, however, potential exposure is minimized, since label instructions generally direct the operator to keep the sprayer nozzle below the grain surface, moving it in zig-zag fashion below the surface while applying the fumigant. At the same time, the operator is directed by label instructions to use a self-contained breathing apparatus while within the structure (Hopes Consulting 1980).

Following fumigation, it is necessary to seal the structure because fumigants are effective only when the grain structure is sufficiently tight to maintain a gas concentration long enough to be lethal to storage pests (Storey et al. 1979). Warning signs are posted and all entrances secured. Enclosures usually remain sealed for 2 to 3 weeks, and are thoroughly aerated before re-entry is permitted.

Because of these standard operating practices and the non-volatile nature of PCBs, it is likely that little, if any, inhalation exposure to PCBs will occur. As a worst case, the maximum PCB level in air could be $2.9 \times 10^{-4} \text{ mg/m}^3$ for a fumigant containing 50 mg/kg PCBs*. If it is assumed that a worker is exposed to this level for 20 hours a week, 48 weeks per year, the annual PCB exposure would be 0.33 mg.

J.4 Estimation of Potential Grain Contamination by PCBs

If PCBs are present in a grain fumigant, then grain treated with the fumigant would be expected to be contaminated with PCBs because the non-volatile nature of PCBs would preclude any significant degree of evaporation from the grain. The degree of contamination could be on the order of $7.4 \times 10^{-2} \text{ mg/kg}$, as estimated using the worst case assumptions listed below:

- It is assumed that the density of the liquid fumigant is 1.33 g/ml**, then a gallon of the fumigant weighs approximately 5 kg (i.e., $1.33 \text{ g/ml} \times 1000 \text{ ml/l} \times 3.785 \text{ l/gal}$).
- If it is assumed that a heavy dose of fumigant, eight gallons per 1,000 bushels, is applied to the grain then the dosage in weight is 40 kg/1,000 bushels (i.e., $8 \text{ gal/1,000 bushels} \times 5 \text{ kg/gal}$).
- If it is assumed that a bushel of grain weighs about 27 kg*** then, 1,000 bushels weigh 27,000 kg.

*This is the equilibrium concentration of PCBs above a solution at 25°C containing 50 mg/kg PCBs as calculated in Attachment D.

**The approximate density of a 3:1 mixture of ethylene dichloride and carbon tetrachloride.

***The weight of a bushel of wheat is approximately 27.2 kg (USDA 1978).

- If it is assumed that the fumigant contains PCBs at a concentration of 50 mg/kg, then the treated grain will have a PCB concentration of 7.4×10^{-2} mg/kg (i.e., $\frac{40 \text{ kg fumigant}}{27,000 \text{ kg grain}} \times \frac{50 \text{ mg PCBs}}{\text{kg fumigant}}$)

It should be noted that PCBs have rarely been detected in samples of grains and cereals. PCBs were detected in only one of 65 samples of grains and cereals analyzed by USDA during 1976, 1977, and 1978. PCBs were found at a trace level in the sample, estimated at 2.5×10^{-2} mg/kg (FDA 1980a, 1980b, 1981).

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ATTACHMENT K

Hypothetical Worker Inhalation Exposure to PCBs During Reactor Charging and Product Drumming Operations

K.1. Introduction

Routine occupational operations such as reactor charging and product drumming can generate aerosols of the liquid or powder being handled to which an involved worker may be exposed (Nicas 1982). If incidentally produced PCBs are present in the liquid or powder, they can be expected to be present in the aerosol.

A recent study on aerosols formed during free-fall of liquids and powders in static air (Sutter et al. 1982) reported that an average of 0.003 weight percent of a "spilled" liquid and 0.019 weight percent of a "spilled" powder can be expected to become airborne in static air when spilled from a height of one meter onto the floor of a room-sized enclosure.

The purpose of this attachment is to use these aerosolization factors to estimate the maximum probable worker exposure to PCBs via inhalation that could result during reactor charging and product drumming operations. This attachment is based primarily on an exposure scenario developed by Nicas (1982).

K.2. Estimation of PCB Air Concentrations for Liquid Handling Operations

If the 0.003 weight percent aerosolization factor is applied to a 55-gallon drumming operation for trichlorobenzene, then the free-fall of 55 gallons of trichlorobenzene could release up to 9.1 g of trichlorobenzene into the airspace in and above the drum (calculation shown below).

$$(55 \text{ gallons}) \times (3.7854 \text{ l/gal}) \times (1.454 \text{ kg/l}) \times (0.003\%) = 9.1 \text{ g}$$

where the density of trichlorobenzene at 20°C is 1.454 kg/l (USEPA 1980).

Because the liquid is being poured into a barrel, which is enclosed on all sides except the top, rather than being spilled onto the floor of a room, the amount of generated aerosol that actually enters the workroom air will be less than 9.1 g due to the "sorption" of aerosol droplets that impact on the sides of the barrel. If it is assumed that only 10 percent of this potential aerosolization actually occurs (Nicas 1982), then up to 0.91 g of trichlorobenzene may be released to the workroom air.

If PCBs are assumed to be present in the trichlorobenzene at a concentration of 50 mg/kg, then 0.046 mg of PCBs can be expected to be released to workroom air. If PCBs are present in the trichlorobenzene at 25 mg/kg or 2 mg/kg, then 0.023 and 0.0018 mg, respectively, of PCBs could be released. If it is assumed that the PCBs are released uniformly into a cubic meter of air above the drum, that this air is replaced 7.6 times a minute*, and that the operation lasts three minutes, then the PCB air concentrations would be 0.002 mg/m³, 0.001 mg/m³, and 0.00008 mg/m³ for PCB product concentrations of 50 mg/kg, 25 mg/kg, and 2 mg/kg, respectively.

K.3. Estimation of PCB Air Concentration for Powder Handling Operations

If the 0.019 weight percent aerosolization factor is applied to an operation involving the dumping of a 50-pound bag of pigment into a reactor, then the free-fall of 50 pounds of pigment could release up to 4.3 grams of pigment into the airspace in and above the reactor (calculation shown below).

$$(50 \text{ lbs.}) \times (0.454 \text{ lb/kg}) \times (0.019\%) = 4.3 \text{ g}$$

*This replacement rate corresponds to an air velocity of about 25 feet per minute. Air with a velocity of 25 feet per minute or less (i.e., 0.28 miles per hour or less) is defined as "still air" (ACGIH 1980).

If, as in Section K.2 above, it is assumed that only 10 percent of this potential aerosolization occurs, then 0.43 grams of pigment may be released to workroom air. If PCBs are assumed to be present in the pigment at a concentration of 50 mg/kg, then 0.022 mg of PCBs can be expected to be released to air. If PCBs are present in the pigment at 25 mg/kg or 2 mg/kg, then 0.011 and 0.00086 mg, respectively, of PCBs could be released. If it is assumed that the PCBs are released uniformly into a cubic meter of air above the reactor, that this air is replaced 7.6 times a minute, and that the operation lasts three minutes, then the PCB air concentrations would be 0.0010 mg/m^3 , 0.0005 mg/m^3 , and 0.00004 mg/m^3 for PCB product concentrations of 50 mg/kg, 25 mg/kg, and 2 mg/kg, respectively.

K.4. Estimation of Individual Annual PCB Exposures

If it is assumed that a typical worker will be involved in product handling operations for a total of 50 hours per year, that the worker has an average inhalation rate of $1.2 \text{ m}^3/\text{hr}$ (Versar 1982), and that respirators are not worn, then the annual PCB exposures resulting from liquid handling operations could be 0.12 mg, 0.06 mg, and 0.005 mg for PCB product concentrations of 50 mg/kg, 25 mg/kg, and 2 mg/kg, respectively; for powder handling operations, the annual PCB exposures could be 0.057 mg, 0.029 mg, and 0.0022 mg for PCB product concentrations of 50 mg/kg, 25 mg/kg, and 2 mg/kg, respectively. The use of protective respiratory equipment and/or local exhaust ventilation to control dust/mist levels would obviously lessen the potential exposure.

References

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ATTACHMENT L

Hypothetical Worker Inhalation Exposure to PCBs During On-Line Repair of Minor Equipment Leaks

L.1. Introduction

The purpose of this attachment is to estimate maximum probable PCB exposures to maintenance workers during repair operations on leaking chemical plant equipment.

L.2. Background

As discussed in Attachment M, EPA is currently in the process of developing regulations to control fugitive emissions of volatile organic compounds (VOC) in the Synthetic Organic Chemicals Manufacturing Industry (SOCMI). During the process of developing these regulations, EPA has compiled data on types of equipment that leak VOCs, the frequency of leaks, and the VOC emission rates.

This attachment will estimate PCB exposure that could result from repair of leaking valves. Leaking valves were selected for the following reasons:

- Unlike many types of leaking equipment, leaking valves can usually be repaired while the system is in operation (i.e., on-line). The basic repair procedure involves tightening and/or repacking of the packing gland (USEPA 1980, 1982).
- Except for flanges, there are more valves in a chemical plant than all other pieces of potentially leaking equipment combined (USEPA 1980, 1982).
- The leak frequency of valves is greater than that of most other types of potentially leaking equipment (USEPA 1980, 1982).
- The valve VOC emission factors estimated for SOCMI compare favorably with actual valve emission rates measured in other industries (USEPA 1982).

L.3. Estimation of PCB Air Concentrations

Table L-1 lists the average VOC emission rates for the three basic types of valves used in chemical operations (USEPA 1982). Table L-1 also lists the maximum expected PCB air concentrations to which a maintenance worker may be exposed for PCB process stream concentrations of 50 mg/kg, 25 mg/kg, and 2 mg/kg. These maximum air levels were estimated using the following equations and assumptions:

$$\text{VOC air concentration} = \frac{(\text{VOC emission rate})}{(\text{air volume}) \times (\text{air exchange rate})} \quad (\text{L-1})$$

where:

- The air volume is assumed to be 1 m³ (i.e., all leaking VOC is uniformly released into a cubic meter of air surrounding the leaking valve).
- The air velocity around the valve is assumed to be 25 feet per minute* (7.6 m/min) (i.e., the cubic meter of air surrounding the valve is replaced 7.6 times a minute).

$$\left(\text{PCB air concentration} \right) = \left(\text{VOC air concentration} \right) \times \left(\text{PCB concentration (kg/kg) in process stream} \right) \quad (\text{L-2})$$

L.4 Estimation of Annual Worker Exposure

To estimate the individual annual exposure to PCBs as a result of on-line equipment repair, it is necessary to estimate the frequency and duration of such repairs. If it is assumed that one of the duties of one maintenance person is the leak detection and repair program for the Model Chemical Plant A, described in Attachment M, then that person is responsible for the maintenance of 362 process valves. (It is assumed that the larger, more complex Model Chemical Plants A and B would require more maintenance personnel).

*Air with a velocity of 25 feet per minute or less (i.e., 0.28 miles per hour or less) is defined as "still air" (ACGIH 1980).

Table L-1. Estimation of PCB Air Concentrations During On-Line Repair of Leaking Valves

| Valve type | VOC emission rate ^a (g/min/valve) | VOC air concentration ^b (g/m ³) | PCB air concentration ^c (ug/m ³) at process streams concentrations of: | | |
|--------------|-------------------------------------------------|-----------------------------------------------------------|--------------------------------------------------------------------------------------------------|----------|---------|
| | | | 50 mg/kg | 25 mg/kg | 2 mg/kg |
| Gas | 4.38 | 0.58 | 29 | 15 | 1.2 |
| Light liquid | 1.42 | 0.19 | 9.5 | 4.8 | 0.38 |
| Heavy liquid | 0.0038 | 0.0005 | 0.025 | 0.013 | 0.001 |

^aSource: USEPA 1982.

^bCalculated using Eqn. L-1 and assuming all VOC are released uniformly into one cubic meter of air which is replaced 7.6 times per minute.

^cCalculated assuming that PCBs are present in the fugitive emissions at the same concentration as they are in the process stream (see Equation L-2).

$$\text{(hours of repair/yr)} = \text{(number of valves)} \times (\% \text{ leaking}) \times \left(\frac{10 \text{ minutes}}{\text{valve repair}}\right) \times \left(\frac{1 \text{ hr.}}{60 \text{ minutes}}\right) \times \left(\frac{4 \text{ inspections}}{\text{year}}\right) \quad (L-3)$$

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Table L-2. Estimation of Time Spent on On-Line Valve Repair Annually

| Valve type | Number of valves in model plant ^a | Leak frequency ^a (%) | Hours spent on repair annually ^b (hrs.) |
|--------------|-------------------------------------------------|------------------------------------|-------------------------------------------------------|
| Gas | 99 | 11.4 | 7.5 |
| Light liquid | 131 | 6.5 | 5.7 |
| Heavy liquid | 132 | 0.4 | 0.4 |

^aSource: USEPA 1980, 1982.

^bCalculated using Equation L-3.

Table L-3. Estimated Annual Individual PCB Exposures

| Valve type | Hours spent annually on repairs ^a (hrs) | PCB air concentration ^b (ug/m ³) at process stream concentrations of: | | | Annual individual exposures ^c (mg/yr) at process stream concentrations of: | | |
|-------------------------------|-------------------------------------------------------|----------------------------------------------------------------------------------------------------|---------|--------|------------------------------------------------------------------------------------------|----------------------|----------------------|
| | | 50mg/kg | 25mg/kg | 2mg/kg | 50mg/kg | 25mg/kg | 2mg/kg |
| Gas | 7.5 | 29 | 15 | 1.2 | 2.6x10 ⁻¹ | 1.4x10 ⁻¹ | 1.1x10 ⁻² |
| Light liquid | 5.7 | 9.5 | 4.5 | 0.38 | 6.5x10 ⁻² | 3.3x10 ⁻² | 2.6x10 ⁻³ |
| Heavy liquid | 0.4 | 0.025 | 0.013 | 0.001 | 1.2x10 ⁻⁵ | 6.2x10 ⁻⁶ | 4.8x10 ⁻⁷ |
| Total exposed ^d | | | | | 0.33 | 0.17 | 0.014 |

^aSource: Table L-2.

^bSource: Table L-1

^cCalculated assuming a breathing rate of 1.2 m³/hr (Versar 1982) and no use of protective respirator equipment.

^dTotal exposure is the sum of the annual exposures for repair of each valve type.

References

ACGIH. 1980. American Conference of Governmental Industrial Hygienists. Industrial ventilation. Ann Arbor, MI: Edwards Brothers, Inc.

USEPA. 1980. VOC fugitive emissions in synthetic organic chemicals manufacturing industry -- background information for proposed standards. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. EPA-450/3-80-003a.

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ATTACHMENT M

Hypothetical Worker Exposure to Background Air Levels of PCBs Resulting from Fugitive Emissions in Enclosed Processing Plants

M.1. Introduction

The purpose of this attachment is to estimate maximum probable occupational exposures to background levels of PCBs in air resulting from fugitive emissions. Fugitive emissions, for the purpose of this attachment, are those emissions that result when process fluid (either liquid or gaseous) leaks from plant equipment. Fugitive emissions do not include emissions resulting from the transfer, spills, storage, treatment, and/or disposal of process wastes.

In order to estimate exposure levels resulting from fugitive emissions, the following pieces of information are required:

- Types and numbers of pieces of equipment that can leak in an organic chemical plant.
- PCB emission factors for pieces of equipment that can leak.
- Size (i.e., volume) of a "typical" enclosed organic chemical plant.
- Ventilation rate of the enclosed plant.

Sections M.2. through M.5. of this attachment discuss each of these required pieces of needed information in order. Section M.6. integrates Sections M.2. through M.5. to estimate maximum probable PCB exposure levels for PCB process stream concentrations of 2 mg/kg, 25 mg/kg, and 50 mg/kg.

M.2. Equipment Types and Counts for Fugitive Emissions

EPA's Office of Air Quality Planning and Standards is currently in the process of finalizing a proposed rulemaking that will establish standards of performance for fugitive emissions of volatile organic compounds (VOC)

from new stationary sources in the Synthetic Organic Chemical Manufacturing Industry (SOCMI). In order to estimate fugitive emissions of VOC, EPA identified the major equipment components that frequently leak and then estimated the number of such components in three model plants. Table M-1 lists the equipment components identified by EPA and the corresponding numbers of each equipment component in three model plant units. The equipment counts for each model plant are based on the results of surveys of process units and on information provided by engineering design and construction firms (USEPA 1980, USEPA 1982).

These model units, which have been used by EPA in its VOC control rulemaking to estimate fugitive emissions of VOC, will be used in this analysis to estimate potential emissions of PCBs.

M.3. Estimated PCB Fugitive Emission Factors

The emission factors that EPA's Office of Air Quality Planning and Standards has used to estimate current fugitive emissions and expected post-regulatory fugitive emissions of VOC from equipment components in SOCMI are shown in Table M-2. They were developed by using (1) SOCMI leak frequencies (i.e., number of leaking and non-leaking fugitive emission sources) and (2) emission factors determined in petroleum refineries and SOCMI units for leaking and non-leaking fugitive emission sources (USEPA 1982).

Table M-2 also lists the estimated PCB emission factors for each type of emission source. These estimated emission factors are based on the assumption that PCBs are present in fugitive emissions at the same weight proportion as in the process stream (i.e., 2 mg/kg or 50 mg/kg).

Based on the estimated PCB emission factors estimated in Table M-2 and the number of emission sources listed in Table M-1, Table M-3 presents estimates of the total PCB fugitive emissions (in mg/hr) under post-regulatory conditions for each of the three model plant units described in Section M.2.

Table M-1. Equipment Counts for Fugitive VOC Emission Sources in
SOCMI Model Units^a

| Emissions source | Equipment counts ^b | | |
|---------------------------|-------------------------------|------------------|------------------|
| | Model Unit A | Model Unit B | Model Unit C |
| Pump seals - light liquid | 8 | 29 | 91 |
| - heavy liquid | 7 | 30 | 93 |
| Valves - gas | 99 | 402 | 1,232 |
| light liquid | 131 | 524 | 1,618 |
| heavy liquid | 132 | 524 | 1,618 |
| Compressor seals | 1 | 2 | 8 |
| Safety release valves | 11 ^c | 42 ^c | 130 ^c |
| Flanges | 600 | 2,400 | 7,400 |
| Sampling connections | 26 ^d | 104 ^d | 320 ^d |

^a Equipment counts as listed in USEPA 1982.

^b 52 percent of existing SOCMI units are similar to Model Unit A.
33 percent of existing SOCMI units are similar to Model Unit B.
15 percent of existing SOCMI units are similar to Model Unit C.

^c 75 percent of safety release valves are assumed to be controlled; therefore, the emission estimates are based on the following counts: A-3; B-11; C-33.

^d 75 percent of the sampling connections are assumed to be controlled; therefore, the emission estimates are based on the following counts: A-7; B-26; C-80.

Table M-2. VOC Emission Factors for Average SOCHI Units
and Estimated PCB Emission Factors

| Emission source | Pre-regulation VOC emission factor ^a (g/hr/source) | Post-regulation VOC emission factor ^a (g/hr/source) | Pre-regulation estimated PCB emission factor ^b (mg/hr/source) | | | Post-regulation estimated PCB emission factor ^b (mg/hr/source) | | |
|----------------------------------------------|---------------------------------------------------------------------|----------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------|-----------------------------|------------------------------------------------------------------------------------|--------------|--------------|
| | | | 2 mg/kg PCB | 50 mg/kg PCB | 2 mg/kg PCB | 2 mg/kg PCB | 50 mg/kg PCB | 50 mg/kg PCB |
| Pump seals - light liquid - heavy liquid | 49.4 21.4 | 19.4 21.4 | 0.10 0.043 | 2.5 1.1 | 0.039 0.043 | 0.97 1.1 | | |
| Valves - gas light liquid heavy liquid | 5.6 7.1 0.23 | 1.5 2.9 0.23 | 0.011 0.014 0.00046 | 0.28 0.36 0.012 | 0.0030 0.0058 0.00046 | 0.075 0.15 0.012 | | |
| Compressor seals | 228 | 0 | 0.46 | 11 | 0 | 0 | | |
| Safety release valves - gas | 104 | 0 | 0.21 | 5.2 | 0 | 0 | | |
| Flanges | 0.83 | 0.83 | 0.0017 | 0.042 | 0.0017 | 0.042 | | |
| Sampling connections | 15.0 | 0 | 0.030 | 0.75 | 0 | 0 | | |

^a As listed in USEPA 1982.

^b See text (Section M.3) for details on estimation methodology.

Table M-3. Estimated Post-Regulation PCB Emissions (mg/hr) for Three Model Plant Units

| Emissions source | Number of sources ^a | | | Estimated post-regulation PCB emissions ^b (mg/hr) | | | | | | | | |
|-----------------------------|--------------------------------|--------|--------|--------------------------------------------------------------|--------|--------|----------|--------|--------|--------|--------|--------|
| | Unit A | Unit B | Unit C | 2 mg/kg | | | 50 mg/kg | | | Unit A | Unit B | Unit C |
| | | | | Unit A | Unit B | Unit C | Unit A | Unit B | Unit C | | | |
| Pump seals - light liquid | 8 | 29 | 91 | 0.31 | 1.1 | 3.6 | 7.8 | 28 | 88 | | | |
| heavy liquid | 7 | 30 | 93 | 0.30 | 1.3 | 4.0 | 7.7 | 33 | 100 | | | |
| Valves - gas | 99 | 402 | 1,232 | 0.30 | 1.2 | 3.7 | 7.4 | 30 | 92 | | | |
| light liquid | 131 | 524 | 1,618 | 0.76 | 3.0 | 9.4 | 20 | 79 | 240 | | | |
| heavy liquid | 132 | 524 | 1,618 | 0.061 | 0.24 | 0.75 | 1.6 | 6.3 | 19 | | | |
| Compressor seals | 1 | 2 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Safety release valves - gas | 3 | 11 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Flanges | 600 | 2,400 | 7,400 | 1.0 | 4.1 | 13 | 25 | 100 | 310 | | | |
| Sampling connections | 7 | 26 | 80 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| Total | | | | 2.7 | 11 | 34 | 70 | 280 | 850 | | | |

^aNumber of emission sources in each model plant are taken from Table M-1.

^bEstimated emissions were calculated by multiplying the estimated PCB emission factors (listed in Table M-2) by the number of emission sources.

M.4. Estimated Size of Enclosed Model Units

Although the majority of organic chemical plants are located outdoors (Baasel 1976) where relatively rapid dispersion and dilution of gaseous fugitive emissions by ambient air can be expected, some processes within a plant as well as some entire plants are enclosed within buildings. The purpose of this attachment is to estimate the levels of PCBs that may be encountered in workplace air in enclosed plants. The estimated size or volume of such plants has been estimated using conservative engineering judgement for the three model plant units described in Section M-2 of this attachment (See Table M-4).

Table M-4. Estimated Sizes of Model Plant Units^a

| | <u>Model plant units</u> | | |
|-------------------------------------|--------------------------|-----------|-----------|
| | Unit A | Unit B | Unit C |
| Plant floor area (ft ²) | 18,000 | 72,000 | 225,000 |
| Plant height (ft) | 14 | 14 | 14 |
| Plant volume (ft ³) | 252,000 | 1,000,000 | 3,150,000 |

^a Based on engineering estimates

M.5. Ventilation Rates in Enclosed Plants

The OSHA standard for ventilation rates in enclosed processing plants using flammable and/or combustible liquids [29 CFR 1910.106 (h) (3) (iii)] mandates a ventilation rate of "not less than one cubic foot per minute per

square foot of solid floor area." Processing plants are defined in the standards as "those plants or buildings which contain chemical operations such as oxidation, reduction, halogenation, hydrogenation, alkylation, polymerization, and other chemical processes."

For the purposes of this assessment, it will be assumed that enclosed organic chemical manufacturing plants that may incidentally produce PCBs or that may use chemicals potentially containing PCBs as chemical intermediates or process solvents must comply with this OSHA standard.

M.6. Integrated Exposure Assessment

Table M-5 presents an integrated assessment of the data presented in Sections M-2 through M-5 to yield estimated in-plant average PCB air concentrations and estimated maximum probable annual individual worker exposures under post-regulatory conditions.

The actual PCB air levels would be expected to be far lower than these worst case estimates for the following reasons:

- Not all fugitive emissions will be to air. A large portion may be liquid leaks onto floor areas. Because of their relatively low vapor pressures, a substantial fraction of any PCBs in such liquid leaks will not vaporize at significant rates.
- The actual sizes of plants are probably larger than those estimated here using conservative engineering judgement.
- The ventilation rates in most enclosed processing plants are expected to be substantially greater than the minimum OSHA-required ventilation rate used in this assessment.

Table M-5. Maximum Occupational Exposures to PCBs From Post-Regulatory Fugitive Emissions in Workplace Air in Enclosed SOCHI Plants

| Model plant | Estimated floor area ^a (ft ²) | Estimated minimum ventilation rate ^b (ft ³ /hr) | Estimated post-regulatory PCB emissions ^c (mg/hr) | | Estimated PCB air level ^d (ug/m ³) | | Annual individual worker exposure ^e (mg/yr) | | |
|-------------|---------------------------------------------------------|--------------------------------------------------------------------------|-----------------------------------------------------------------|----------|--------------------------------------------------------------|----------|-----------------------------------------------------------|----------|----------|
| | | | 2 mg/kg | 50 mg/kg | 2 mg/kg | 50 mg/kg | 2 mg/kg | 25 mg/kg | 50 mg/kg |
| A | 18,000 | 1,080,000 | 2.7 | 70 | 0.09 | 2.3 | 0.21 | 2.6 | 5.3 |
| B | 72,000 | 4,320,000 | 11 | 280 | 0.09 | 2.3 | 0.21 | 2.6 | 5.3 |
| C | 225,000 | 13,500,000 | 34 | 850 | 0.09 | 2.2 | 0.21 | 2.5 | 5.1 |

^aEstimated floor areas as listed in Table M-4.

^bVentilation rate based on 1 ft³/min per ft² of floor area (see Section M.4 for details). The ventilation rates correspond to an air exchange rate of about 4.3 air changes per hour.

^cEstimated PCB emissions as listed in Table M-3 (see Section M.3 for details.) This assessment assumes that 100 percent of the PCB fugitive emissions are released to air.

^dAssuming steady-state conditions, the PCB concentration, C, with ventilation rate, V, is $C = N/V$, where N is the PCB emission rate. (The conversion factor, 1 m³ = 35.31 ft³, is incorporated into the estimated levels listed).

^eAnnual individual worker exposure assumes exposure to the estimated PCB concentration for 40 hours per week for 48 weeks per year with no use of respirators. A breathing rate of 1.2 m³/hr, corresponding to the mean of the average breathing rates for medium activity and low activity stress levels (Versar 1982), was assumed. Annual exposures for PCB process stream concentration of 25 mg/kg were calculated assuming the air levels were one-half the air levels for a process stream concentration of 50 mg/kg.

References

Baasel WD. 1976. Preliminary chemical engineering plant design. New York, NY: American Elsevier Publishing Company, Inc.

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USEPA. 1982. Fugitive emission sources of organic compounds -- additional information on emissions, emission reductions, and costs. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. EPA-450/3-82-010.

Versar. 1982. Methodology for assessing exposure to toxic chemicals in the ambient environment. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances. Contract No. 68-01-6271.

ATTACHMENT N

Hypothetical PCB Inhalation Exposure for a Worker Stationed Downwind of Leaking Equipment

N.1. Introduction

The purpose of this attachment is to estimate maximum probable PCB exposure via inhalation to a worker stationed near leaking equipment. The exposure is calculated for a worker stationed downwind from a mix tank/transfer pump installation inside an enclosed building.

N.2. Estimation of PCB Emissions

As discussed in Attachment M, EPA is currently in the process of developing regulations to control fugitive emissions of volatile organic compounds (VOC) in the synthetic organic chemicals manufacturing industry. During the process of developing these regulations, EPA has compiled data on types of equipment that leak, the frequency of leaks, and the associated VOC emission rates (USEPA 1982).

Schroy (1981) has estimated the types and numbers of potential fugitive emission sources that can be expected on a mix tank/transfer pump installation. Schroy's data are combined in Table N-1 with EPA's emission rates to provide estimates of potential PCB emission rates for hypothetical PCB process stream concentrations of 50 mg/kg, 25 mg/kg, and 2 mg/kg. All fugitive emissions are assumed to be released to air, and PCBs are assumed to be present in the fugitive emissions at the same weight proportion as in the process stream (i.e., 50 mg/kg, 25 mg/kg, or 2 mg/kg).

N.3. Estimated PCB Air Concentrations

The maximum downwind concentration of PCBs to which a worker may be exposed can be calculated using an air dispersion model reported by Schroy 1981. This model (Equation N-1) is designed to predict maximum

Table N-1. Estimated PCB Emissions from a Mix Tank/Pump Unit

| Fugitive emission sources in mix tank/pump unit ^a | VOC emission factor ^b (g/hr/source) | Number of sources ^a | Estimated PCB emission rate ^c (mg/hr) | | |
|-----------------------------------------------------------------|---------------------------------------------------|-----------------------------------|--------------------------------------------------|------------|------------|
| | | | 2 mg/kg | 25 mg/kg | 50 mg/kg |
| Flanges | 0.83 | 10 | 0.017 | 0.21 | 0.42 |
| Light liquid valve seals | 7.1 | 4 | 0.057 | 0.71 | 1.4 |
| Light liquid pump seals | 49.4 | 1 | 0.099 | 1.2 | 2.5 |
| Agitator seal | 49.4 | 1 | <u>0.099</u> | <u>1.2</u> | <u>2.5</u> |
| | | | = 0.27 | = 3.3 | = 6.8 |

^aThe types and numbers of fugitive emission sources in a theoretical mix tank/pump unit were described in Schroy 1981.

^bVolatile organic compound (VOC) emission factors for flanges, valve seals and pump seals are listed as reported in USEPA 1982. Schroy 1981 claims that the emission factor for an agitator seal is similar to the emission factor for pump seals.

^cCalculated as follows for each type of source:

$$(\text{PCB emission rate}) = (\text{VOC emission factor}) \times (\text{number of sources}) \times \left(\text{PCB concentration in the process stream} \right)$$

downwind concentrations as a function of distance from the source, where the dispersed emissions plume does not reflect from a solid surface.

$$C = [1337.786] \times [Q/(M \times u)] \times [1/(2\pi\sigma_y\sigma_z)] \quad (N-1)$$

where,

C = predicted PCB air concentration (ppm)

Q = PCB emission rate (g/hr)

M = molecular weight of PCBs = 266.5 (i.e., molecular weight of Aroclor 1242).

u = velocity of workplace air passing the point of release (fpm)

σ_y and σ_z = vertical and horizontal dispersion coefficients (m)
which are functions of the distance from the leak source.

The predicted maximum PCB concentrations at distances of 3, 6, and 9 meters from the mix tank/transfer pump installation are listed in Table N-2 for the PCB emission rates listed in Table N-1. These predicted concentrations assume a low velocity of air passing the point of release, 25 fpm*.

N.4. Estimated Annual Worker Exposure to PCBs

Table N-2 also lists the annual PCB exposures that could result from being stationed at a work site located 3, 6, or 9 meters from the mix tank/transfer pump installation.

*Air with a velocity of 25 fpm or less (i.e., 0.28 miles per hour or less) is defined as "still air" (ACGIH 1980). The minimum air velocity recommended by the ACGIH for worker comfort at fixed work stations is 50 fpm. (Ollshifski 1981).

Table N-2. Estimated PCB Air Levels and Associated Annual Individual Worker Exposure

| Distance from source (m) | Value of $[1/2\pi\sigma_y\sigma_z)]$ for Eqn N-1(a) (m^{-2}) | Estimated PCB air level ^b ($\mu g/m^3$) | | | Annual individual worker exposure ^c (mg/yr) | | |
|-----------------------------|-------------------------------------------------------------------|---------------------------------------------------------|----------|----------|-----------------------------------------------------------|----------|----------|
| | | 2 mg/kg | 25 mg/kg | 50 mg/kg | 2 mg/kg | 25 mg/kg | 50 mg/kg |
| 3 | 0.08120 | 0.048 | 0.59 | 1.2 | 0.11 | 1.4 | 2.8 |
| 6 | 0.05507 | 0.032 | 0.40 | 0.82 | 0.074 | 0.92 | 1.9 |
| 9 | 0.04188 | 0.025 | 0.30 | 0.62 | 0.058 | 0.69 | 1.4 |

^aThese values are taken from Schroy 1981.

^bThe estimated PCB air levels were calculated using Equation N-1 and assuming an air velocity of 25 fpm. The results of Equation N-1 which are expressed in ppm were converted to $\mu g/m^3$ for this table. For Aroclor 1242, 1 ppm equals $10.9 \times 10^3 \mu g/m^3$ at 25°C and 760 mm Hg.

^cAnnual individual worker exposure assumes exposure to the estimated PCB concentration for 40 hours per week for 48 weeks per year with no use of respirators. A breathing rate of $1.2 m^3/hr$, corresponding to the mean of the average breathing rates for medium activity and low activity stress levels (Versar 1982) was assumed.

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Versar. 1982. Methodology for assessing exposure to toxic chemicals in the ambient environment. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances. Contract No. 68-01-6271.

ATTACHMENT O

Hypothetical Worker Inhalation Exposure to PCBs Associated with Spray Painting Mist

0.1. Introduction

The purpose of this attachment is to estimate maximum probable worker exposure to PCBs contained in aerosols generated during industrial spray painting activities.

The major constituents in paints can be grouped into three general categories: binders, pigments, and volatile solvents. Chemicals that are either known to contain incidentally produced PCBs (i.e., exemption petitions have been submitted to EPA) or are suspected of containing PCBs are sometimes used in each of these constituent categories. For example, vinyl resin binders are commonly based on vinyl chloride and vinylidene chloride. Phthalocyanine pigments are commonly used for imparting blue or green colors to automobiles, appliances, office furniture, and many other products. Chlorinated benzenes and ethanes, although not widely used as paint solvents, are occasionally used for this function.

0.2. Estimation of PCB Concentration in Paint

The PCB concentration in a final formulated paint will depend on (1) the PCB concentration in the contaminated binder, pigment, or solvent; (2) the relative weight fraction of the contaminated binder, pigment, or solvent to the respective binder system, pigment system, or solvent system (typically more than one solvent and one pigment are used in a paint, and the binder system often comprises more than one resin type combined with cross-linking agents, plasticizers, etc.); and (3) the relative weight percentages of the binder system, pigment system, and solvent system in a final formulated paint. This relationship is described by Equation O-1.

$$C_{FFP} = [(C_{BC}) \times (W_{BC}) \times (W_{BS})] + [(C_{PC}) \times (W_{PC}) \times (W_{PS})] + [(C_{SC}) \times (W_{SC}) \times (W_{SS})] \quad (O-1)$$

where

C_{FFP} = PCB concentration in final, formulated paint (mg/kg),

C_{BC} = PCB concentration in binder system component (mg/kg),

W_{BC} = relative weight fraction of the contaminated binder component to the binder system (e.g., if the contaminated binder component comprises 70% by weight of the binder system then $W_{BC} = 0.7$),

W_{BS} = relative weight fraction of the binder system to the final, formulated paint,

C_{PC} = PCB concentration in the pigment system component (mg/kg),

W_{PC} = relative weight fraction of the contaminated pigment component to the pigment system,

W_{PS} = relative weight fraction of the pigment system to the final, formulated paint,

C_{SC} = PCB concentration in the solvent system component (mg/kg),

W_{SC} = relative weight fraction of the contaminated solvent component to the solvent system, and

W_{SS} = relative weight fraction of the solvent system to the final, formulated paint.

The relative weight percentages of binder, pigment, and solvents in a final, formulated paint will depend upon the method/equipment by which the paint will be applied, the type of binder and solvent systems being used, the desired depth of coating on the substrate, and the color intensity desired.

As examples of the PCB levels that hypothetically could be found in industrial paint, Table 0-1 lists the PCB levels expected in two types of paint formulations: a relatively low solids content paint (i.e., 34% binder system, 6% pigment system, 60% solvent system) and a relatively high solids content paint (i.e., 54% binder system, 6% pigment system, and 40% solvent system). The PCB containing binder component in each

Table O-1. Hypothetical PCB Concentrations in Paint

| Paint type | PCB concentration in contaminated system component (mg/kg) | | | PCB concentration in final paint ^a (mg/kg) | |
|------------|------------------------------------------------------------|---------|---------|-------------------------------------------------------|---------------------------|
| | Binder | Pigment | Solvent | Low solids content paint | High solids content paint |
| 1 | 50 | 50 | 50 | 28 | 30 |
| 2 | 25 | 25 | 25 | 14 | 15 |
| 3 | 50 | 0 | 0 | 12 | 19 |
| 4 | 25 | 0 | 0 | 6 | 9.5 |
| 5 | 0 | 50 | 0 | 0.75 | 0.75 |
| 6 | 0 | 25 | 0 | 0.38 | 0.38 |
| 7 | 0 | 0 | 50 | 15 | 10 |
| 8 | 0 | 0 | 25 | 8 | 5 |

^aThe PCB concentrations in final, formulated paints were calculated using Equation O-1. The low solids content paint is assumed to contain by weight 34% binder system, 6% pigment system, and 60% solvent system. The high solids content paint is assumed to contain by weight 54% binder system, 6% pigment system, and 40% solvent system. In both types of solids content paint, the contaminated binder is assumed to account for 70% by weight of the binder system; the contaminated pigment is assumed to account for 25% by weight of the pigment system; and the contaminated solvent is assumed to make up 50% by weight of the solvent system.

type of paint is assumed to make up 70% by weight of the binder system. This is the typical weight percentage of vinyl chloride resins in a vinyl chloride-based binder system; the remaining 30% consists mainly of plasticizers (NIOSH 1981). The PCB containing pigment component in each type of paint is assumed to account for 25% by weight of the pigment system. Except for electrostatically-applied powder paints, the pigment system is typically about 6% by weight of the final paint (NIOSH 1981); phthalocyanine pigments are not expected to exceed 1.5% by weight of a final paint (DCMA 1981). The PCB containing solvent component in each type of paint is assumed to account for 50% by weight of the solvent system. Except for paints containing mineral spirits or water, no solvent is typically more than 50% of the solvent system (NIOSH 1981).

0.3. Estimation of PCB Air Levels and Annual Worker PCB Exposures

Because of the non-volatile nature of PCBs (see Attachment D), virtually all potential worker inhalation exposure to PCBs during spray painting will result from inhalation of paint aerosols rather than inhalation of volatilized PCBs. The non-volatile component of a paint aerosol (i.e., the resin system, the pigment system, and non-volatile solvent components) is referred to as paint mist. If the paint composition is known, the concentration of non-volatile paint components such as PCBs in paint mist can be calculated. Table 0-2 presents the calculated PCB concentrations in the paint mists associated with the assumed paint types listed in Table 0-1.

Paint mists are regulated by OSHA under the nuisance dust standard (29 CFR 1910.1000) (NIOSH 1981). This standard requires that the eight-hour, time-weighted average particulate concentration in air be maintained at levels no greater than 15 mg/m^3 . If it is assumed that paint mist is present in workplace air at this maximum allowed level, then the maximum potential worker exposure to PCBs contained in the paint mist can be estimated. Table 0-2 presents these estimated maximum PCB air concentrations and annual individual worker exposures for the assumed paint types listed in Table 0-1. Table 0-3 lists actual concentrations of paint mists reported in a recent in-depth survey of worker exposures to paint mists in the ten different industrial spray painting operations (NIOSH 1981).

Table O-2. Estimated PCB Air Concentrations and Individual Annual Exposures to PCBs Associated with Paint Mist

| Paint type ^a | PCB concentration in final formulated paint ^a (mg/kg) | | PCB concentration in paint mist ^b (mg/kg) | | Estimated PCB air concentration ^c (ug/m ³) | | Estimated individual annual exposure ^d (mg/yr) | |
|-------------------------|------------------------------------------------------------------|-------------------|------------------------------------------------------|-------------------|-------------------------------------------------------------------|-------------------|-----------------------------------------------------------|-------------------|
| | Low solids paint | High solids paint | Low solids paint | High solids paint | Low solids paint | High solids paint | Low solids paint | High solids paint |
| 1 | 28 | 30 | 70 | 50 | 1.1 | 0.75 | 2.5 | 1.7 |
| 2 | 14 | 15 | 35 | 25 | 0.53 | 0.38 | 1.1 | 0.88 |
| 3 | 12 | 19 | 30 | 32 | 0.45 | 0.48 | 1.0 | 1.1 |
| 4 | 6.0 | 9.5 | 15 | 16 | 0.23 | 0.24 | 0.53 | 0.55 |
| 5 | 0.75 | 0.75 | 1.9 | 1.2 | 0.028 | 0.018 | 0.064 | 0.041 |
| 6 | 0.38 | 0.38 | 0.95 | 0.63 | 0.014 | 0.010 | 0.032 | 0.023 |
| 7 | 15 | 10 | 38 | 17 | 0.57 | 0.26 | 1.3 | 0.60 |
| 8 | 7.5 | 5.0 | 19 | 8.3 | 0.28 | 0.12 | 0.64 | 0.28 |

^aSource: Table O-1.

^bA paint aerosol refers to droplets of paint in air. Paint mist, which is regulated by OSHA, refers only to the non-volatile portion of a paint aerosol. Paint mist, therefore, comprises primarily the binder and pigment systems. Any non-volatile components of the solvent system, such as PCB contaminants, would be considered part of the paint mist. The PCB concentration in paint mist is calculated by dividing the PCB concentration in the final formulated paint by the ratio of the non-volatile mass of the final paint to the mass of the final paint. For example, the low solids content paint type number 1 has a PCB concentration of 28 mg/kg. This paint type has a non-volatile mass equal to 40% of the total paint mass (i.e., 34% binder and 6% pigment). The solvent system, except for any PCB contaminant, is assumed to be volatile. Therefore, the PCB concentration in the paint mist is calculated to be 70 mg/kg (i.e., $28 \text{ mg/kg} \times \frac{40\%}{100\%}$). Thus, the net effect is that any PCBs present in the solvent would become concentrated in the paint mist because of evaporation of the solvent.

^cCalculated by multiplying the OSHA nuisance dust standard (i.e., 15 mg/m³) by the PCB concentration in paint mist as a weight fraction.

^dCalculated assuming exposure for 40 hours per week, 48 weeks per year at a breathing rate of 1.2 m³/hr (Versar 1982), and no use of protective respirator equipment.

Table O-3. Results of Monitoring Studies of Paint Mist Levels^a

| Operation | 8-Hr time-weighted average paint mist concentration (mg/m ³) | | |
|-------------------------------|--------------------------------------------------------------------------|------|---------|
| | Minimum | Mean | Maximum |
| Powder coating of small parts | 1.3 | 1.4 | 1.5 |
| Wood furniture | 0.1 | 0.7 | 2.5 |
| File cabinet | 2.9 | 4.2 | 6.2 |
| Metal furniture ^b | 3.7 | 12.6 | 27.6 |
| Appliances ^c | 21.7 | 34.7 | 54.5 |
| Railroad freight cars | 9.6 | 10.8 | 11.8 |
| Heavy equipment | 1.3 | 3.1 | 7.4 |
| Automotive refinishing | 2.3 | 5.0 | 9.4 |
| Light aircraft | 1.6 | 4.9 | 10.3 |
| Sheet metal touchup | 0.5 | 0.7 | 0.9 |

^aSource: NIOSH 1981. The mist concentrations reported are the levels to which a worker not wearing protective equipment would be exposed.

^bRespirators and hoods were worn by all workers during spray painting operations.

^cThe spray painting of appliance liners comprised only 10% of the painting time but contributed significantly to the time-weighted average mist concentration. Average mist concentrations during all other spray operations were less than 15 mg/m³. Respirators were worn by all painters during the painting of appliance liners (NIOSH 1981).

OSHA also indirectly regulates paint mist levels in industrial spray painting booths through the standards regulating ventilation rates in spray booths (29 CFR 1910.94). Spray booths that meet these minimum OSHA ventilation requirements should be capable of controlling paint mist to average levels of 5 mg/m³ (NIOSH 1981).

References

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NIOSH. 1981. National Institute for Occupational Safety and Health. An evaluation of engineering control technology for spray painting. Cincinnati, OH: NIOSH. DHHS (NIOSH) Publication No. 81-121.

Versar. 1982. Methodology for assessing exposure to toxic chemicals in the ambient environment. Draft final report. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances. Contract No. 68-01-6271.

ATTACHMENT P

Hypothetical Worker Inhalation Exposure to PCBs Associated with Mineral Oil Mist

P.1. Introduction

The purpose of this attachment is to estimate maximum probable worker inhalation exposure to PCBs potentially present in mineral oil mist. Mineral oil mist is defined as the mist of the following petroleum-based products: white mineral oils; cutting oils; heat-treating oils; hydraulic oils; cable oils; transformer oils; lubricating oils; and drawing oils (NIOSH 1981). Hypothetically, mineral oil could become contaminated with PCBs via several pathways including the following:

- Additives, such as biocides and extreme pressure compounds, which are commonly added to mineral oil may contain incidentally produced PCBs.
- Incidentally produced PCBs may be present in pesticides or inks for which mineral oil is used as the carrier vehicle.
- Mineral oil used in transformers which previously had contained PCB fluids may contain residual levels of PCBs.

The following list includes some common uses of mineral oil which can result in generation of mineral oil mist to which workers may be exposed (NIOSH 1981):

- Use as a coolant or quenching agent in machine shop operations and metal fabrication.
- Use during coating and cleaning operations in foundries.
- Use in steel rolling operations.
- Use in lubricating and cleaning of machinery.
- Use in printing press operations.
- Use in mine drilling operations.
- Use as a pesticide carrier vehicle.

P.2. Estimation of PCB Concentrations in Mineral Oil

The concentration of incidentally produced PCBs in mineral oil will depend on both the PCB concentration in the additive/pesticide/ink and on the concentration of the additive/pesticide/ink in the mineral oil. This relationship is described by Equation P-1.

(P-1)

$$\begin{array}{l} \text{(PCB concentra-} \\ \text{tion in} \\ \text{mineral oil)} \end{array} = \begin{array}{l} \text{(PCB concentration} \\ \text{in additive/} \\ \text{pesticide/ink)} \end{array} \times \begin{array}{l} \text{(weight fraction of the} \\ \text{additive/pesticide/ink in} \\ \text{the formulated oil)} \end{array}$$

Table P-1 lists the PCB concentrations expected in mineral oil for nine combinations of assumed PCB concentrations in the additive/pesticide/ink and assumed additive/pesticide/ink concentrations in mineral oil.

P.3. Estimation of PCB Air Concentrations and Annual Worker PCB Exposures

Because of the non-volatile nature of PCBs (see Attachment D) and their high degree of solubility in organic liquids such as mineral oil, virtually all potential worker inhalation exposure to PCBs present in mineral oil will result from inhalation of mineral oil mist rather than inhalation of volatilized PCBs. Mineral oil mists are regulated by OSHA (29 CFR 1910.1000). The current OSHA standard for mineral oil mist is 5 mg/m^3 averaged over an eight-hour work shift.

If it is assumed that mineral oil mist is present in workplace air at this maximum allowed level, then the maximum potential worker exposure to PCBs contained in the mist can be estimated. Table P-2 presents the estimated maximum PCB air concentrations and annual individual worker exposures for the nine hypothetical mineral oil types listed in Table P-1 as well as for three hypothetical transformer mineral oils contaminated with different levels of residual PCBs.

Table P-3 lists the results of several monitoring studies performed by NIOSH for oil mist levels in various settings. The results indicate that, in most instances, oil mist levels are kept below 5 mg/m^3 .

Table P-1. Estimated PCB Concentrations in Mineral Oil Mist

| Mineral oil type | PCB concentration in additive/pesticide/ink (mg/kg) | Additive/pesticide/ink concentration in mineral oil (weight %) | PCB concentration in mineral oil ^a (mg/kg) |
|------------------|-----------------------------------------------------|----------------------------------------------------------------|-------------------------------------------------------|
| 1 | 50 | 25 | 12.5 |
| 2 | 50 | 10 | 5.0 |
| 3 | 50 | 2 | 1.0 |
| 4 | 25 | 25 | 6.25 |
| 5 | 25 | 10 | 2.5 |
| 6 | 25 | 2 | 0.5 |
| 7 | 2 | 25 | 0.5 |
| 8 | 2 | 10 | 0.2 |
| 9 | 2 | 2 | 0.04 |

^aPCB concentrations in mineral oil were calculated using Equation P-1 for the assumed PCB concentrations in the additive listed in column 2 and the assumed additive concentrations in mineral oil listed in column 3.

Table P-2.

Estimated PCB Air Concentrations and Individual
Annual Exposures to PCBs Associated with Mineral Oil Mist

| Mineral oil type | PCB concentration in mineral oil ^a (mg/kg) | Estimated PCB air concentration ^b (ug/m ³) | Estimated individual annual exposure ^c (mg/yr) |
|---------------------|----------------------------------------------------------|----------------------------------------------------------------------|--------------------------------------------------------------|
| 1 | 12.5 | 6.3×10^{-2} | 1.5×10^{-1} |
| 2 | 5.0 | 2.5×10^{-2} | 5.8×10^{-2} |
| 3 | 1.0 | 5.0×10^{-3} | 1.2×10^{-2} |
| 4 | 6.25 | 3.1×10^{-2} | 7.1×10^{-2} |
| 5 | 2.5 | 1.3×10^{-2} | 3.0×10^{-2} |
| 6 | 0.5 | 2.5×10^{-3} | 5.8×10^{-3} |
| 7 | 0.5 | 2.5×10^{-3} | 5.8×10^{-3} |
| 8 | 0.2 | 1.0×10^{-3} | 2.3×10^{-3} |
| 9 | 0.04 | 2.0×10^{-4} | 4.6×10^{-4} |
| 10 | 50 | 2.5×10^{-1} | 5.8×10^{-1} |
| 11 | 25 | 1.3×10^{-1} | 2.9×10^{-1} |
| 12 | 2 | 1.0×10^{-2} | 2.3×10^{-2} |

^aThe PCB concentrations in mineral oil types 1 through 9 were calculated using Equation P-1 and the assumptions listed in Table P-1. The PCB concentrations for mineral oil types 10, 11, and 12 are hypothetical levels of PCBs in mineral oils used in transformers.

^bThe PCB concentration in air is calculated by multiplying the OSHA standard for mineral oil mist (i.e., 5 mg/m³) by the PCB concentration in mineral oil as a weight fraction.

^cThe individual annual exposure is calculated assuming exposure to the estimated PCB air concentration for 40 hours per week, 48 weeks per year with no use of respirators at a breathing rate of 1.2 m³/hr (Versar 1982).

Table P-3.

Results of Monitoring Studies of Oil Mist Levels^a

| Operation | Oil mist air concentration (mg/m ³) | | | Reference |
|---------------------------------------|-------------------------------------------------|------|---------|-------------|
| | minimum | mean | maximum | |
| Machining of steel auto parts | 0.7 | 0.4 | 1.0 | NIOSH 1978a |
| Newspaper printing press | 1.0 | 3.0 | 6.2 | NIOSH 1978b |
| Machining of steel medical equipment | 0.2 | 1.4 | 3.7 | NIOSH 1978c |
| Aluminum rolling | 0.5 | 1.0 | 1.4 | NIOSH 1978d |
| Machining of steel and aluminum | 0.1 | 0.3 | 1.5 | NIOSH 1978e |
| Manufacture of drilling machine parts | 0.2 | 1.8 | 12.0 | NIOSH 1979a |
| Manufacture of heavy machinery | 0.25 | 0.50 | 1.0 | NIOSH 1979b |
| Machining of aluminum and steel | <0.1 | 0.51 | 3.1 | NIOSH 1979c |
| Newspaper printing press | 0.1 | 0.7 | 1.7 | NIOSH 1979d |
| Aluminum foundry | 0.15 | 0.36 | 0.64 | NIOSH 1979e |

^aThis list includes all NIOSH Health Hazard Evaluation Reports with report call numbers that range from 520 to 620 (i.e., the last three-digit segment of the report number) and which contain monitoring data on oil mist.

^bAll data represent personal breathing zone concentrations.

References

- NIOSH. 1978a. Health Hazard Evaluation Determination, Chevrolet Transmission Plant No. 1, Toledo, Ohio. Cincinnati, OH: National Institute for Occupational Safety and Health. Report HE-77-108-520.
- NIOSH. 1978b. Health Hazard Evaluation Determination, Chicago Tribune, Chicago, IL. Cincinnati, OH: National Institute for Occupational Safety and Health. Report No. HE-77-069-522.
- NIOSH. 1978c. Health Hazard Evaluation Determination, Hosal Medical Corp., Littleton, CO. Cincinnati, OH: National Institute for Occupational Safety and Health. Report No. HE-78-070-528.
- NIOSH. 1978d. Health Hazard Evaluation Determination, Alcan Aluminum Corp., Fairmont, WV. Cincinnati, OH: National Institute for Occupational Safety and Health. Report No. HE-78-088-533.
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ATTACHMENT Q

Hypothetical Worker Inhalation Exposure to PCBs During Open-Surface Tank Operations

Q.1. Introduction

The purpose of this attachment is to estimate maximum probable worker exposure to PCBs that may be released to workplace air during open-surface tank operations. Open-surface tank operations are defined by OSHA (29 CFR 1910.94(d)) as all operations involving the immersion of materials in liquids, or in the vapors of such liquids, for the purpose of cleaning or altering the surface or adding to or imparting a finish thereto or changing the character of the materials, and their subsequent removal from the liquid or vapor, draining, and drying. These operations include washing, electroplating, anodizing, pickling, quenching, dyeing, dipping, tanning, dressing, bleaching, degreasing, stripping, rinsing, and other similar operations but do not include surface coating operations.

Although PCBs are not expected to be incidentally produced during open-surface tank operations, they may be present in the liquids used in some of these operations. For example, PCBs may be incidentally produced during the manufacture of some chlorinated solvents that are commonly used in degreasing operations and as dye carriers in certain dyeing operations. Any PCBs present in these liquids could theoretically enter workplace air via evaporation. In addition to evaporation, mists are commonly generated during some open-surface tank operations that involve air agitation or gassing of the tank liquid*. However, this potential pathway of PCB entry into air is not addressed in this attachment because

*Although some open-surface tank operations involve spraying of the tank liquid onto the work piece, OSHA regulations require that sufficient enclosure or baffling be provided to prevent the discharge of spray into the workroom (29 CFR 1910.94 (d)).

mist-generating conditions are generally limited to aqueous solution operations (ACGIH 1980, ANSI 1971), such as electroplating and metal pickling, in which chlorinated solvents potentially containing PCBs are not used.

Maximum probable levels of PCBs in workplace air that would result from evaporation during open-surface tank operations are estimated in Sections Q.2 and Q.3. Section Q.2 estimates PCB air levels for a generic, open-surface tank operation based on a NIOSH study (Flanigan et al. 1974) of design criteria for exhaust systems for open-surface tanks. Section Q.3 estimates PCB air levels resulting from use of specific, OSHA-regulated chlorinated solvents in open-surface tank operations such as degreasing tanks.

Q.2. Estimated PCB Air Concentrations Resulting from Evaporation from a Generic Open-Surface Tank

Q.2.1. Background

The maximum air levels of PCBs that could result from evaporation of PCBs from liquids were estimated in Attachment D for PCB concentrations in the liquid of 50 mg/kg, 25 mg/kg, and 2 mg/kg. Because of general room ventilation and hood exhaust at the surface tank, these estimated levels would only be expected relatively near the surface of the tank. The PCB levels in workplace air are expected to be considerably lower than these estimated maximum levels.

To estimate what the workplace air concentrations could be, the results of a NIOSH study in which design criteria for exhaust systems for open-surface tanks were developed will be used (Flanigan et al. 1974). In this NIOSH study, experiments measuring the levels of ethanol in air were conducted for varying parameters of surface tank operation such as temperature and hood exhaust rates. The ethanol was present at a four percent (by weight) level in the tank liquid. The experiments were conducted under laboratory conditions designed to simulate real-life

conditions of open-surface tank use. A full-sized, open-surface tank (4-ft length by 8-ft width) exhausted by a single-slot lateral hood (i.e., exhausted from only one side of the tank) was used for the experiments.

Q.2.2. Estimation of Air Concentrations of Evaporated PCBs

The maximum air levels of PCBs estimated in Attachment D were calculated using Raoult's Law and Dalton's Law of Partial Pressure. Raoult's Law was employed to estimate the equilibrium partial pressure of PCBs above the liquid. Once the equilibrium partial pressure was estimated, Dalton's Law was used to estimate the maximum PCB air levels at equilibrium. This same estimation methodology can be used to estimate the maximum air levels of ethanol expected as a result of volatilization from the NIOSH model open-surface tank. Table Q-1 lists the equilibrium partial pressures and maximum ethanol air levels at equilibrium for tank temperatures of 25°C, 50°C, and 75°C.

Table Q-2 lists the actual workplace air concentrations of ethanol that were measured by Flanigan et al. (1974) for tank temperatures of 50°C and 75°C; no experiments were performed using tank temperature of 25°C. Table Q-2 also lists the ratio of the actual measured ethanol concentration to the estimated maximum ethanol concentration above the tank liquid at equilibrium. If it is assumed that the difference between the measured concentrations and the maximum equilibrium concentrations is due to the dilution effects of general room ventilation and hood exhaust at the surface of the liquid, then this ratio can also be expected to apply for actual levels of PCBs in workplace air and the maximum equilibrium concentrations of PCBs that were calculated in Attachment D. Table Q-3 lists the expected workplace PCB air concentrations assuming that this relationship is valid.

Table Q-1. Equilibrium Partial Pressures and Air Concentrations of Ethanol Above the NIOSH Model Tank

| Tank temperature (°C) | Equilibrium partial pressure of ethanol above tank ^a (torr) | Maximum ethanol air concentration at equilibrium ^b (mg/m ³) |
|--------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| 25 | 5 | 12,400 |
| 50 | 20 | 49,000 |
| 75 | 80 | 198,000 |

^aThe equilibrium partial pressures above the tank were measured in Flanigan et al. (1974).

^bThe maximum air concentrations at equilibrium were calculated using Dalton's Law of Partial Pressures (see Attachment D, Section 2, for details on this estimation methodology).

Table Q-2. Measured Workplace Air Concentrations of Ethanol

| Tank temperature (°C) | Measured ethanol air concentration ^a (mg/m ³) | Maximum ethanol air concentration at equilibrium ^b (mg/m ³) | Ratio of measured to estimated maximum equilibrium concentration |
|-----------------------|----------------------------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------|
| 25 | - | 12,400 | - |
| 50 | 28 | 49,000 | 5.7x10 ⁻⁴ |
| 75 | 210 | 198,000 | 1.1x10 ⁻³ |

^aThese are the measured concentrations (Flanigan et al. 1974) when the surface tank hood exhaust rate was 100 ft³ of air per minute for each ft² of tank surface area. This hood exhaust rate is the minimum hood exhaust rate required by OSHA (29 CFR 1910.94(d) for an open-surface tank with dimensions of 4 feet long and 8 feet wide that generates gas, vapor, or mist. No measurements were made at tank temperatures less than 50°C.

^bSource: Table Q-1.

Table Q-3. Expected Workplace Air Concentrations of PCBs Evaporated from a Generic Open-Surface Tank

| Tank temperature (°C) | PCB concentration in tank liquid (mg/kg) | Maximum PCB concentration at equilibrium ^a (mg/m ³) | Ratio of expected workplace concentration to equilibrium concentration ^b | Expected workplace concentration ^c (mg/m ³) |
|-----------------------|------------------------------------------|----------------------------------------------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------|
| 50 | 50 | 4.3x10 ⁻³ | 5.7x10 ⁻⁴ | 2.4x10 ⁻⁶ |
| | 25 | 2.2x10 ⁻³ | 5.7x10 ⁻⁴ | 1.2x10 ⁻⁶ |
| | 2 | 1.7x10 ⁻⁴ | 5.7x10 ⁻⁴ | 9.7x10 ⁻⁸ |
| 75 | 50 | 5.0x10 ⁻² | 1.1x10 ⁻³ | 5.5x10 ⁻⁵ |
| | 25 | 2.5x10 ⁻² | 1.1x10 ⁻³ | 2.8x10 ⁻⁵ |
| | 2 | 2.0x10 ⁻³ | 1.1x10 ⁻³ | 2.2x10 ⁻⁶ |

^aSource: Attachment D, Table D-2.

^bSource: Table Q-2.

^cCalculated by multiplying the maximum PCB concentration at equilibrium by the ratio of expected workroom concentration to equilibrium concentration.

Q.2.3. Estimation of Annual Individual Worker Exposure to PCBs
Evaporated from a Generic Open-Surface Tank

Table Q-4 lists the estimated annual individual worker exposures for the estimated PCB levels in workplace air listed in Table Q-3.

Q.3. Estimated PCB Air Concentrations Resulting from Use of
OSHA-Regulated Chlorinated Solvents

Q.3.1. Background

Chlorinated solvents, potentially containing incidentally produced PCBs, are commonly used to remove grease, wax, dirt and other undesirable matter from various substrates ranging from metals and plastics to textiles (Hoogheem et al. 1979). These cleaning operations are generically termed "degreasing operations" and, for the most part, are considered open-surface tank operations by OSHA. The types of degreasing operations performed in the United States fall into four categories which are: (1) cold cleaning; (2) fabric scouring; (3) open top vapor degreasing; and (4) conveyORIZED vapor degreasing (Hoogheem et al. 1979). Cold cleaning and fabric scouring operations typically involve using solvents at room temperature or colder temperatures. In open top and conveyORIZED vapor degreasing operations, the substrate is cleaned by contacting it with solvent vapor; the solvent is maintained at elevated temperature, often at the boiling point. The solvents can enter workroom air by evaporation from the tank itself, through the substrate inlets and outlets (for partially enclosed degreasers), and from solvent wet substrates after removal from the degreaser (Hoogheem et al. 1979).

Q.3.2. Estimation of Air Concentrations of Evaporated PCBs

The maximum PCB air levels above a solution containing low concentrations of PCBs were calculated in Attachment D using Raoult's Law and Dalton's Law of Partial pressures. This same methodology can be used to estimate the maximum air levels of a chlorinated degreasing solvent. Table Q-5 lists the equilibrium vapor pressures and maximum air levels of six commonly used chlorinated solvents. Table Q-5 also lists the ratio of the OSHA standards for the chemicals to their maximum air levels at equilibrium.

Table Q-4. Estimated Annual Individual Worker Exposure to PCBs Evaporated from a Generic Open-Surface Tank

| Tank temperature (°C) | PCB concentration in tank liquid (mg/kg) | Expected workplace PCB concentration ^a (mg/m ³) | Annual individual worker exposure ^b (mg/yr) |
|--------------------------|------------------------------------------------|------------------------------------------------------------------------------|--------------------------------------------------------------|
| 50 | 50 | 2.4×10^{-6} | 5.5×10^{-3} |
| | 25 | 1.2×10^{-6} | 2.8×10^{-3} |
| | 2 | 9.7×10^{-8} | 2.2×10^{-4} |
| 75 | 50 | 5.5×10^{-5} | 1.3×10^{-1} |
| | 25 | 2.8×10^{-5} | 6.5×10^{-2} |
| | 2 | 2.2×10^{-6} | 5.1×10^{-3} |

^aSource: Table Q-3.

^bCalculated assuming exposure for 40 hours per week, 48 weeks per year with no respirator use, and a breathing rate of 1.2 m³/hr.

Table Q-5. Estimation of Maximum Solvent Vapor Pressures and Air Concentrations at Equilibrium

| Solvent | Molecular weight | Tank temperature ^a (C°) | Vapor pressure of solvent (torr) | Maximum solvent air concentration at equilibrium ^b (mg/m ³) | OSHA limit (mg/m ³) | Ratio of OSHA limit to maximum equilibrium concentration |
|--------------------------|------------------|------------------------------------|----------------------------------|------------------------------------------------------------------------------------|---------------------------------|----------------------------------------------------------|
| Carbon tetrachloride | 153.82 | 25 76.7 | 113 760 | 9.35x10 ⁵ 6.29x10 ⁶ | 6.3 | 6.7x10 ⁻⁶ 1.0x10 ⁻⁶ |
| Methyl chloroform | 133.41 | 25 74 | 99 760 | 7.11x10 ⁵ 5.46x10 ⁶ | 1,910 | 2.7x10 ⁻³ 3.5x10 ⁻⁴ |
| Methylene chloride | 84.92 | 25 39.8 | 438 760 | 2.00x10 ⁶ 3.47x10 ⁶ | 1,740 | 8.7x10 ⁻⁴ 5.0x10 ⁻⁴ |
| Tetrachloroethylene | 165.83 | 25 121 | 14 760 | 1.25x10 ⁵ 6.78x10 ⁶ | 680 | 5.4x10 ⁻³ 1.0x10 ⁻⁴ |
| Trichloroethylene | 131.39 | 25 86.7 | 59 760 | 4.17x10 ⁵ 5.37x10 ⁶ | 540 | 1.3x10 ⁻³ 1.0x10 ⁻⁴ |
| Trichlorotrifluoroethane | 187.38 | 25 47.7 | 284 (20°C) 760 | 2.86x10 ⁶ 7.66x10 ⁶ | 7,600 | 2.6x10 ⁻³ 9.9x10 ⁻⁴ |

^aTank temperature of 25°C corresponds to typical temperature of cold cleaning and fabric scouring operations. The other temperature listed for each solvent is the solvent boiling point which is the expected temperature for vapor degreasing operations.

^bThe maximum solvent air concentrations at equilibrium were calculated using Daltons Law of Partial Pressures (see Attachment D, Section 2, for details on this estimation methodology).

Table Q-6 lists the maximum PCB air concentrations at equilibrium above solutions of the six chlorinated solvents assuming that the solvents contain 50 mg/kg PCBs. These concentrations were estimated using Raoult's Law and Dalton's Law of Partial Pressures as outlined in Attachment D. Concentrations were estimated for solvent temperatures of 25°C (corresponding to cold cleaning and fabric scouring operations) and the boiling points of the solvents (corresponding to vapor degreasing operations).

If it is assumed that the difference between the OSHA limits for the solvents and their maximum air levels at equilibrium is due to dilution effects of general room ventilation and local exhausts, then this ratio can also be expected to apply for actual levels of PCBs in workplace air and the maximum PCB air concentrations at equilibrium as estimated in Table Q-6. Table Q-6 lists the expected maximum PCB air concentrations assuming that this relationship is valid.

Q.3.3. Estimation of Annual Individual Worker Exposure to PCBs
Evaporated from Chlorinated Solvents

Table Q-6 also lists the estimated annual individual worker exposures for the maximum expected PCB levels in workplace air.

Table Q-6. Maximum Expected Workplace Air Concentrations of PCBs Evaporated From Chlorinated Solvents
(assuming solvents contain 50 mg/kg PCBs)

| Solvent | Tank temperature (°C) | Maximum PCB air concentration at equilibrium ^a (mg/m ³) | Ratio of OSHA limit to maximum solvent air concentration ^b | Maximum expected PCB air concentration ^c (mg/m ³) | Maximum annual individual worker exposure ^d (mg/yr) |
|--------------------------|-----------------------|--------------------------------------------------------------------------------|-----------------------------------------------------------------------|--------------------------------------------------------------------------|----------------------------------------------------------------|
| Carbon tetrachloride | 25 | 1.6x10 ⁻⁴ | 6.7x10 ⁻⁶ | 1.1x10 ⁻⁹ | 2.6x10 ⁻⁶ |
| | 76.7 | 2.9x10 ⁻² | 1.0x10 ⁻⁶ | 2.9x10 ⁻⁸ | 6.7x10 ⁻⁵ |
| Methyl chloroform | 25 | 1.4x10 ⁻⁴ | 2.7x10 ⁻³ | 3.9x10 ⁻⁷ | 8.9x10 ⁻⁴ |
| | 74 | 2.5x10 ⁻² | 3.5x10 ⁻⁴ | 8.8x10 ⁻⁶ | 2.0x10 ⁻² |
| Methylene chloride | 25 | 9.1x10 ⁻⁵ | 8.7x10 ⁻⁴ | 8.0x10 ⁻⁸ | 1.8x10 ⁻⁴ |
| | 39.8 | 6.8x10 ⁻⁴ | 5.0x10 ⁻⁴ | 3.4x10 ⁻⁷ | 7.8x10 ⁻⁴ |
| Tetrachloroethylene | 25 | 1.8x10 ⁻⁴ | 5.4x10 ⁻³ | 9.6x10 ⁻⁷ | 2.2x10 ⁻³ |
| | 121 | 4.5x10 ⁻¹ | 1.0x10 ⁻⁴ | 4.5x10 ⁻⁵ | 1.0x10 ⁻¹ |
| Trichloroethylene | 25 | 1.4x10 ⁻⁴ | 1.3x10 ⁻³ | 1.8x10 ⁻⁷ | 4.2x10 ⁻⁴ |
| | 86.7 | 3.5x10 ⁻² | 1.0x10 ⁻⁴ | 3.5x10 ⁻⁶ | 8.1x10 ⁻³ |
| Trichlorotrifluoroethane | 25 | 2.0x10 ⁻⁴ | 2.6x10 ⁻³ | 5.2x10 ⁻⁷ | 1.2x10 ⁻³ |
| | 47.7 | 3.0x10 ⁻³ | 9.9x10 ⁻⁴ | 3.0x10 ⁻⁶ | 6.9x10 ⁻³ |

^aMaximum PCB air concentrations at equilibrium were calculated using Raoult's Law and Dalton's Law of Partial Pressures (see Attachment D, Section 2, for details on this estimation methodology). The molecular weight of PCBs was assumed to be 266.5 (i.e., the molecular weight of Aroclor 1242). The vapor pressure of PCBs in pure form at the tank temperatures listed in the table are based on data provided by Hutzinger et al. (1974) for Aroclor 1242: at 25°C, VP = ~4x10⁻⁴ torr; at 39.8°C, VP = ~3x10⁻³ torr; at 47.7°C, VP = ~6x10⁻³ torr; at 74-76.7°C, VP = ~7x10⁻² torr; at 86.7°C, VP = ~0.1 torr; at 121°C, VP = ~1 torr.

^bSource: Table Q-5.

^cCalculated by multiplying the maximum PCB concentration at equilibrium by the ratio of the OSHA solvent limit to the maximum solvent air concentration at equilibrium.

^dCalculated assuming exposure for 40 hours per week, 48 weeks per year with no respirator use, and a breathing rate of 1.2 m³/hr (Versar 1982).

References

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ATTACHMENT R

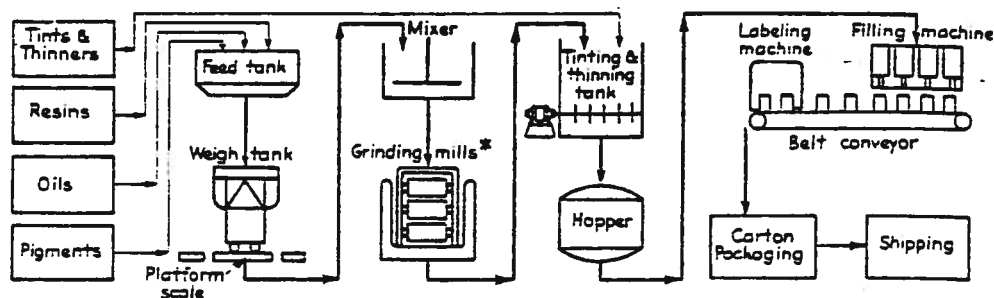
Hypothetical Worker Inhalation Exposure to PCBs During Paint Formulation Operations

R.1. Introduction

Incidental production of PCBs during paint formulation operations is not expected because these operations are physical processes carried out at room temperature and involve no chemical reactions. However, as discussed in Attachment O, chemicals that are either known to contain incidentally produced PCBs or are suspected of containing PCBs are sometimes used as the raw materials in paint formulation (e.g., binders, pigments, and solvents).

R.2. Potential Sources of Worker Exposure to PCBs

The major operations involved in paint formulation are charging the mixer, mixing, grinding, thinning adjustment, filling, and labeling. This process scheme is illustrated in the figure below (Schreve 1967).



NOTE: Because a complete paint factory consumes upward of 2000 different raw materials and produces ten times as many finished products, it is not possible to give yields, etc.

**Many types of grinding mills are used in the same plant either in series or in parallel. Some of them are buhrstone, coffee, and single-, three- and five-roll steel mills*

Most paints are formulated at room temperature in batches ranging in size from 250 to 6,000 gallons. Although many batches are custom formulated, the industry trend is to increase batch size in order to reduce costs (USEPA 1977, 1979). Except for small batches, most paint formulation and transfer operations are performed automatically (Martens 1969) with little direct worker contact with the raw materials or the paint. The exception to this generalization involves handling of pigments. Because the color of a paint is dependent on the very small quantity of pigment present, the weighing and addition of pigment to the feed tank may frequently be performed manually. During the weighing and addition of pigment, a worker can be exposed via inhalation of pigment dusts.

Although most operations are performed automatically, there is still the potential for worker inhalation exposure to PCBs as a result of: (1) fugitive dust emissions from the solids mixing tank and grinding mills; (2) evaporation emissions from the tinting and thinning tanks (although these tanks mechanically mix the paint components, the degree of liquid agitation is not expected to be sufficient to cause significant misting because any misting would result in loss of a relatively expensive product); and (3) evaporative emissions from equipment leaks and spills. The maximum estimated individual exposures to PCBs for each of these three emission sources are listed in Table R-1 for three hypothetical PCB concentrations in the dust or paint.* Worker exposure to PCBs can also occur during sampling and maintenance activities. Potential inhalation exposure during these activities is generically addressed in Attachment D.

*The actual estimation of potential PCB exposures via inhalation of dusts and evaporated PCBs were developed in Attachments F and S, respectively.

Table R-1. Estimation of Maximum Probable Worker
Inhalation Exposure to PCBs

| Exposure type | PCB concentration in dust/paint (mg/kg) | Individual annual worker exposure ^{a,b} (mg/yr) |
|----------------------------------------------------------------------------------------------------------------|-----------------------------------------------|----------------------------------------------------------------------|
| Inhalation of pigment and resin dusts generated during solids handling and mixing/grinding operations | 50 25 2 | 1.7 8.8×10^{-1} 6.9×10^{-2} |
| Inhalation of PCBs evaporated from open surfaces (i.e., open tanks, leaks, spills) | 50 25 2 | 5.3×10^{-3} 2.5×10^{-3} 2.1×10^{-4} |

^aMaximum annual exposure to PCBs in airborne dust that were calculated in Appendix F are applicable to this scenario as a worst-case estimate. Because of the characteristic batch-type operations of this industry and the wide variety and types of products manufactured, it is unlikely that pigments and resins potentially containing PCBs are continuously being used.

^bAnnual exposures to PCBs that evaporate from coating surfaces at 25°C that have an exposed surface area equal to 30 percent of the room's floor area were calculated in Attachment S and are assumed to be applicable to this scenario as a worst-case approximation of the surface area of open mixing, thinning, and tinting tanks, and spills.

References

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ATTACHMENT S

Hypothetical Worker Inhalation Exposure to PCBs During Non-Spray Coating Operations (Mechanical Application)

S.1. Introduction

The purpose of this attachment is to estimate maximum probable worker inhalation exposure to PCBs that may be released via evaporation during non-spray coating operations involving the use of materials, such as chlorinated solvents, which may contain incidentally produced PCBs. A coating process is the application of a liquid to a substrate for either functional purposes (e.g., waterproofing, flameproofing, insulation, or adhesion) or decorative purposes (e.g., blue or green coloration on wrapping paper) (Zink 1979).

The coating operations covered by this attachment include all processes in which the coating is mechanically applied to the substrate, exclusive of spray-coating operations and open-surface tank operations which are addressed separately in Attachments O and Q, respectively. Examples of coating operations addressed by this attachment are (1) dip coating operations in which a substrate is immersed in a tank, vat, or container of the formulated coating; (2) flow coating operations in which a stream of coating is squirted through orifices at the substrate and then drains away to leave a uniform coating; and (3) roll coating in which the substrate is passed directly through a tank or trough, or over the surface of a roller that revolves partially submerged in the coating formulation (Zink 1979, Martens 1969).

S.2. Basic Assumptions

The following basic assumptions are made in the development of the exposure scenario in this attachment:

- Any PCBs present in the coating formulation are not reacted with or physically bound within any coating component and are therefore free to evaporate in a manner akin to evaporation from a liquid solution.

- Because the coating operations covered in this attachment do not include spraying operations, the only mechanism by which PCBs can enter air is via evaporation.
- Workers may be exposed to PCBs evaporating during the coating operation and conveying operations; however, all operations involving highly elevated temperatures (i.e., in excess of 75°C), such as curing and drying ovens, are assumed to be ventilated in accordance with OSHA standards (29 CFR 1910.106) and therefore not to contribute to worker exposure.

S.3. Estimation of PCB Evaporation Rates

The evaporation rate data required to estimate emission rates for individual PCB isomers are not available. In lieu of these data, the evaporation rate that has been determined for Aroclor 1242 at 100°C will be used to estimate potential PCB evaporation rates at other temperatures.

Aroclor 1242 is a commercial mixture of PCB isomers. Molecules containing four or fewer chlorine atoms make up more than 90 percent (by weight) of the mixture. Although the average number of chlorine atoms per molecule in the mixture is 3.1, the vapor pressure of the mixture is greater than would be expected for a pure trichlorobiphenyl because of the bias imparted by the components of lower chlorine content (Hutzinger et al. 1974).

At 100°C, the vapor pressure of pure Aroclor 1242 is approximately 5×10^{-1} torr, and its evaporation rate is $0.338 \text{ mg/cm}^2/\text{hr}$ (Hutzinger et al. 1974). Although the evaporation rates of Aroclor 1242 at other temperatures have not been experimentally measured, they can be roughly estimated by assuming a direct proportionality between evaporation rate and vapor pressure at different temperatures.* The estimated evaporation rates of Aroclor 1242 at 25°C, 50°C, and 75°C are listed in

*This assumption has been verified using the methods for determining evaporation rates and diffusivity coefficients presented in Welty et al. (1976) and Perry and Chilton (1973).

Table S-1 for concentrations of Aroclor in a liquid of 50 mg/kg, 25 mg/kg, and 2 mg/kg. The equilibrium partial pressures of Aroclor 1242 above the liquid were estimated using Raoult's Law (see Attachment D for details).

S.4. Estimation of PCB Air Concentrations and Annual Worker Exposures

Using the evaporation rates estimated in Section S.3, the maximum probable levels of PCBs in workroom air can be estimated using the following assumptions:

- The room in which the coating operation is performed has a ceiling height of 10ft (or 3.0m). This is the ceiling size determined in a NIOSH study (Flanigan et al. 1974) to be representative of ceiling heights in rooms in which open surface tanks are used. The room is assumed to have a floor surface area of 100m².
- The general ventilation in the room is assumed to be six air changes per hour. This is the minimum ventilation rate required by OSHA for a room with a ceiling height of 10ft whenever flammable or combustible liquids are handled or used in unit physical operations such as mixing, drying, dipping, filtering, and similar operations which do not involve chemical change (29 CFR 1910.106 (e)).
- It is assumed that the ratio of the exposed surface area of the coating (i.e., in the vat/trough and on freshly coated substrates) to the floor surface area of the room ranges from 0.1 to 0.3 (engineering judgment). Therefore, assuming a floor surface area of 100m², the exposed coating surface area ranges from 10m² to 30m².

Table S-2 lists the estimated PCB air concentrations for the various coating temperatures, PCB concentrations in the coating, and exposed coating surface areas. Table S-3 lists the estimated annual exposures for a worker continuously exposed to these concentrations.

Table S-1. Estimated Evaporation Rates of Aroclor 1242

| PCB concentration in coating (mg/kg) | Coating temperature (°C) | Partial pressure of Aroclor 1242 above coating ^a (torr) | Proportionality factor ^b | Evaporation rate ^c (mg/cm ² /hr) |
|--------------------------------------------|--------------------------------|-----------------------------------------------------------------------------|----------------------------------------|--------------------------------------------------------------|
| 50 | 75 | 3.5×10^{-6} | 7.0×10^{-6} | 2.4×10^{-6} |
| | 50 | 3.0×10^{-7} | 6.0×10^{-7} | 2.0×10^{-7} |
| | 25 | 2.0×10^{-8} | 4.0×10^{-8} | 1.4×10^{-8} |
| 25 | 75 | 1.8×10^{-6} | 3.6×10^{-6} | 1.2×10^{-6} |
| | 50 | 1.5×10^{-7} | 3.0×10^{-7} | 1.0×10^{-7} |
| | 25 | 1.0×10^{-8} | 2.0×10^{-8} | 6.8×10^{-9} |
| 2 | 75 | 1.4×10^{-7} | 2.8×10^{-7} | 9.5×10^{-8} |
| | 50 | 1.2×10^{-8} | 2.4×10^{-8} | 8.1×10^{-9} |
| | 25 | 8.0×10^{-10} | 1.6×10^{-9} | 5.4×10^{-10} |

^aPartial pressures of Aroclor 1242 above the coating were calculated using Raoult's Law (see Attachment D for details).

^bThe proportionality factor is the ratio of the partial pressure of Aroclor 1242 above the coating to the vapor pressure of pure Aroclor 1242 at 100°C (i.e., 5×10^{-1} torr) (Hutzinger et al. 1974).

^cIt is assumed that the evaporation rates of Aroclor 1242 at different temperatures are proportional to the ratio of the vapor pressures at the corresponding temperatures. Because the evaporation rate of Aroclor 1242 has been reported only for 100°C, the evaporation rate at any other temperature is estimated as follows:

$$\left(\begin{array}{l} \text{evaporation rate at} \\ \text{temperature T} \end{array} \right) = \left(\begin{array}{l} \text{proportionality} \\ \text{factor} \end{array} \right) \times \left(\begin{array}{l} \text{evaporation rate} \\ \text{at 100°C} \end{array} \right)$$

where the evaporation rate at 100°C = $0.338 \text{ mg/cm}^2/\text{hr}$ (Hutzinger et al. 1974).

Table S-2. Estimated PCB Air Concentrations

| PCB concentration in coating (mg/kg) | Coating temperature (°C) | Evaporation rate ^a (mg/cm ² /hr) | Maximum PCB air concentrations ^b (mg/m ³) for exposed surface areas of: | | |
|--------------------------------------------|--------------------------------|--------------------------------------------------------------|---------------------------------------------------------------------------------------------------|------------------------|------------------------|
| | | | 10m ² | 20m ² | 30m ² |
| 50 | 75 | 2.4 x 10 ⁻⁶ | 1.3 x 10 ⁻⁴ | 2.7 x 10 ⁻⁴ | 4.0 x 10 ⁻⁴ |
| | 50 | 2.0 x 10 ⁻⁷ | 1.1 x 10 ⁻⁵ | 2.2 x 10 ⁻⁵ | 3.3 x 10 ⁻⁵ |
| | 25 | 1.4 x 10 ⁻⁸ | 7.8 x 10 ⁻⁷ | 1.6 x 10 ⁻⁶ | 2.3 x 10 ⁻⁶ |
| 25 | 75 | 1.2 x 10 ⁻⁶ | 6.7 x 10 ⁻⁵ | 1.3 x 10 ⁻⁴ | 2.0 x 10 ⁻⁴ |
| | 50 | 1.0 x 10 ⁻⁷ | 5.5 x 10 ⁻⁶ | 1.1 x 10 ⁻⁵ | 1.7 x 10 ⁻⁵ |
| | 25 | 6.8 x 10 ⁻⁹ | 3.8 x 10 ⁻⁷ | 7.6 x 10 ⁻⁷ | 1.1 x 10 ⁻⁶ |
| 2 | 75 | 9.5 x 10 ⁻⁸ | 5.3 x 10 ⁻⁶ | 1.1 x 10 ⁻⁵ | 1.6 x 10 ⁻⁵ |
| | 50 | 8.1 x 10 ⁻⁹ | 4.5 x 10 ⁻⁷ | 9.0 x 10 ⁻⁷ | 1.4 x 10 ⁻⁶ |
| | 25 | 5.4 x 10 ⁻¹⁰ | 3.0 x 10 ⁻⁸ | 6.0 x 10 ⁻⁸ | 9.0 x 10 ⁻⁸ |

^aEvaporation rates were calculated and listed in Table S-1.

^bPCB air concentrations were calculated as follows using the assumptions listed in Section 5.3.

$$(\text{PCB air concentration}) = \frac{(\text{PCB evaporation rate}) \times (\text{exposed coated surface area}) \times (10^4 \text{ cm}^2/\text{m}^2)}{(\text{room air volume of } 300\text{m}^3) \times (6 \text{ air changes/hr})}$$

Table S-3. Estimated Annual Individual Worker Exposure

| PCB concentration in coating (mg/kg) | Coating temperature (°C) | Annual individual worker exposure ^a (mg/yr) for exposed coating surface areas of: | | |
|--------------------------------------------|--------------------------------|-------------------------------------------------------------------------------------------------|----------------------|----------------------|
| | | 10m ² | 20m ² | 30m ² |
| 50 | 75 | 3.0×10^{-1} | 6.2×10^{-1} | 9.2×10^{-1} |
| | 50 | 2.5×10^{-2} | 5.1×10^{-2} | 7.6×10^{-2} |
| | 25 | 1.8×10^{-3} | 3.7×10^{-3} | 5.3×10^{-3} |
| 25 | 75 | 1.5×10^{-1} | 3.0×10^{-1} | 4.6×10^{-1} |
| | 50 | 1.3×10^{-2} | 2.5×10^{-2} | 3.9×10^{-2} |
| | 25 | 8.8×10^{-4} | 1.8×10^{-3} | 2.5×10^{-3} |
| 2 | 75 | 1.2×10^{-2} | 2.5×10^{-2} | 3.7×10^{-2} |
| | 50 | 1.0×10^{-3} | 2.1×10^{-3} | 3.2×10^{-3} |
| | 25 | 6.9×10^{-5} | 1.4×10^{-4} | 2.1×10^{-4} |

^aAnnual exposures to the air concentrations listed in Table S-2 were calculated assuming exposure for 40 hours per week, 48 weeks per year with no respirator use and a breathing rate of 1.2 m³/hr (Versar 1982).

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ATTACHMENT T

Hypothetical Exposure of Workers to PCBs During Pesticide Spraying

T.1. Introduction

Application of pesticides by air-blast spraying generally produces greater potential for worker exposure to pesticides than other methods of application, since finely divided spray is directed upward into the air and is more likely to settle on the operator. The fine mists produced lead to potentially high inhalation and dermal exposure for workers applying the pesticides.

Though many studies have been conducted to evaluate worker exposure during air-blast pesticide spraying, the most extensive work has been done by Wolfe et al. (1967, 1972). In these studies, pesticide exposure was measured by direct means. Respiratory exposure was estimated from the analysis of contaminated respirator filter pads worn by workers. Dermal contamination was measured by attaching absorbent pads to exposed body parts. Hand contamination was measured by analysis of solvent rinsings. The total dermal exposure was the sum of the exposures of unclothed body parts.

Exposure rates from these Wolfe studies are listed in Table T-1 in terms of mg of active pesticide potentially inhaled or deposited on the skin for each hour of exposure; the range and mean exposure rates are listed in the table. Potential PCB exposure rates are developed in this scenario assuming hypothetical concentrations of 50, 25, and 2 mg/kg in the active pesticide portion of the spray.

T.2 Estimation of PCB Exposures

Pesticide exposure data from studies by Wolfe, et al. (1967, 1972) are presented in terms of the amount of exposure to active pesticides, in milligrams, for each hour of spraying activity. If it is assumed that

Table T-1. Hypothetical PCB Exposures from Pesticide Airblast Spraying

| Exposure Route (mg/yr) | PCB concentration (mg/kg) | Pesticide exposure rate (mg/hr) ^a | PCB exposure rate (mg/hr) ^b | Annual PCB exposure (mg/yr) ^c |
|---------------------------|------------------------------|-------------------------------------------------|-------------------------------------------|------------------------------------------------|
| Inhalation | 50 | 0.02 (Lower limit) | 1.0×10^{-6} | 4.8×10^{-4} |
| | | 0.07 (Mean) | 3.5×10^{-6} | 1.7×10^{-3} |
| | | 0.26 (Upper limit) | 1.3×10^{-5} | 6.2×10^{-3} |
| | 25 | 0.02 | 5.0×10^{-7} | 2.4×10^{-4} |
| | | 0.07 | 1.8×10^{-6} | 8.6×10^{-4} |
| | | 0.26 | 6.5×10^{-6} | 3.1×10^{-3} |
| | 2 | 0.02 | 4.0×10^{-8} | 1.9×10^{-5} |
| | | 0.07 | 1.4×10^{-7} | 6.7×10^{-5} |
| | | 0.26 | 5.2×10^{-7} | 2.5×10^{-4} |
| Dermal | 50 | 15.5 (Lower limit) | 7.8×10^{-4} | 3.7×10^{-1} |
| | | 34.5 (Mean) | 1.7×10^{-3} | 8.2×10^{-1} |
| | | 75.1 (Upper limit) | 3.8×10^{-3} | 1.8 |
| | 25 | 15.5 | 3.9×10^{-4} | 1.9×10^{-1} |
| | | 34.5 | 8.6×10^{-4} | 4.1×10^{-1} |
| | | 75.1 | 1.9×10^{-3} | 9.1×10^{-1} |
| | 2 | 15.5 | 3.1×10^{-5} | 1.5×10^{-2} |
| | | 34.5 | 6.9×10^{-5} | 3.3×10^{-2} |
| | | 75.1 | 1.5×10^{-4} | 7.2×10^{-2} |

^aRates taken from pesticide air-blast application studies by Wolfe et al. (1967, 1972). Lower and upper limits represent extremes of exposure rate range for inhalation and dermal routes; mean values were calculated from 17 exposure rate averages. Exposure estimates assume that no respirators or protective clothing are worn.

^bPCB exposure rate, mg/hr = (PCB concentration/10⁶) x (hourly pesticide exposure rate).

^cAnnual PCB exposure, mg/yr = (PCB exposure rate) x (40 hrs/week) x (12 wks/yr).

PCBs are present in this active portion of the pesticide spray at the three given concentrations, the hypothetical PCB exposure rate is easily calculated as a proportion of the total pesticide exposure rate. For example, if PCBs are present in the pesticide at 50 mg/kg, and the rate of inhalation of the active pesticide ingredient is 0.07 mg/hr, the hypothetical PCB exposure rate is calculated as follows:

$$\frac{50}{10^6} \times (0.07 \text{ mg/hr}) = 3.5 \times 10^{-6} \text{ mg/hr}$$

Table T-1 presents hypothetical PCB exposure rates (mg/hr) and the projected annual exposures for each PCB concentration level in active pesticide. Exposure rates and annual exposures are calculated based on the mean, and upper and lower limits of pesticide exposure rates presented by Wolfe et al. (1967, 1972).

The estimated annual PCB exposures are based on exposure durations of 40 hours per week and 12 weeks per year. In actual practice, spraying is usually seasonal and broken up into separate periods of a few days in duration. Although a professional pesticide applicator may be exposed more frequently than 12 weeks per year, it is unlikely that the professional will always be using pesticides potentially contaminated with incidentally produced PCBs. Therefore, the PCB exposures presented in Table T-1 represent reasonable worst case situations. In addition, the exposure estimates assume that no protective equipment or respirators are worn by the worker.

References

Wolfe HR, et al. 1967. Exposure of workers to pesticides. Archives of Environmental Health. 14:622.

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ATTACHMENT U

Hypothetical Worker Inhalation Exposure to PCBs During Dry-Cleaning Operations

U.1. Introduction

The purpose of this attachment is to estimate maximum probable worker exposure to PCBs during garment dry-cleaning operations. The most commonly used dry-cleaning solvent is perchloroethylene. PCBs are known to be incidentally produced during the manufacture of perchloroethylene and therefore may be present at low concentrations in the final, manufactured product.

U.2. Background

It is estimated that 70 percent of the volume of garment dry-cleaning in the United States is carried out with chlorinated hydrocarbon solvents; the remaining 30 percent is carried out with petroleum-based solvents such as Stoddard solvent (Reich 1979). Perchloroethylene is the predominantly used chlorinated hydrocarbon solvent. Fluorocarbon 113 (i.e., 1,1,2-trichloro-1,2,2-trifluoroethane) is only used to a limited extent because of its relatively high cost and because its high volatility (boiling point of 47°C) necessitates the use of expensive, specially constructed equipment to minimize emissions. Trichloroethylene and 1,1,1-trichloroethane are used as solvents at a small number of industrial dry-cleaning establishments (Reich 1979, NIOSH 1980).

It is assumed that the PCB emission sources in a dry-cleaning operation are the same as the perchloroethylene emission sources. The major perchloroethylene emission source is evaporation of perchloroethylene from solvent-damp garments during manual transfer of the garments from the washing machine to the drying machine; of secondary importance is evaporation of perchloroethylene through leaking washer and

dryer door gaskets, dryer aeration dampers, and lint traps. Minor emission sources include (1) evaporation of perchloroethylene during draining and replacement of solvent filters used to remove fugitive dyes and insoluble soils from the solvent; (2) evaporation via leaks in solvent purification stills; and (3) evaporation of any residual solvent in the clothes during pressing operations to remove wrinkles (NIOSH 1980).

U.3. Estimation of PCB Air Concentrations

Virtually all perchloroethylene that enters workroom air enters by means of evaporation rather than aerosol formation. The use of spray guns during spotting operations (i.e., the selective application of chemicals to loosen or remove specific stains from garments) could generate some aerosols, but the intermittent nature of this operation, the small quantity of chemicals used, and the small amount of time typically spent doing spotting minimize the contribution of spotting to chemical levels in air (NIOSH 1980).

The major sources of perchloroethylene emissions, and therefore potential PCB emissions, were identified in Section U.2 as primarily evaporation from pre-dried garments and, of secondary importance, leaks from the washing and drying machines. Washing is carried out at room temperature, and drying is carried out at temperatures less than 75°C (Reich 1979). Thus, most perchloroethylene emissions, and therefore PCB emissions, are occurring at relatively low temperatures, 25°C to 75°C.

The maximum possible PCB air levels above a solution containing low concentrations of PCBs were calculated in Attachment D using Raoult's Law and Dalton's Law of Partial Pressures. This same methodology can be used to estimate the maximum air levels of perchloroethylene expected as a result of volatilization from liquid films on garments and solvent liquid in the washing machine. Table U-1 lists the equilibrium vapor pressures and maximum perchloroethylene air levels for liquid temperatures of 25°C, 50°C, and 75°C.

Table U-1. Estimation of Maximum Perchloroethylene Vapor Pressures and Air Concentrations at Equilibrium

| System temperature (°C) | Equilibrium vapor pressure of perchloroethylene ^a (torr) | Maximum perchloroethylene air concentration at equilibrium ^b (mg/m ³) | Ratio of maximum permissible to maximum equilibrium concentration ^c |
|-------------------------|---------------------------------------------------------------------|----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| 25 | 14 | 1.25×10^5 | 5.4×10^{-3} |
| 50 | 60 | 4.94×10^5 | 1.4×10^{-3} |
| 75 | 200 | 1.53×10^6 | 4.4×10^{-4} |

^aExcept for contaminants, the dry cleaning solvent is assumed to be pure perchloroethylene. Therefore, the equilibrium vapor pressures are equal to the vapor pressures of the pure substance. Vapor pressure at 25°C was obtained from USEPA (1981). The vapor pressures at 50°C and 75°C were obtained from Perry and Chilton (1973). (The vapor pressure listed for 75°C is the vapor pressure at 79.8°C.)

^bThe maximum equilibrium air concentrations were calculated using Dalton's Law of Partial Pressures (see Attachment D, Section 2, for details on this estimation methodology). The molecular weight of perchloroethylene is 165.83 (USEPA 1981).

^cRatio was calculated by dividing 680 mg/m³ (i.e., the OSHA 8-hour time-weighted average permissible exposure level) by the maximum equilibrium concentration.

Most dry-cleaning establishments comply with OSHA's current permissible exposure level of 680 mg/m^3 perchloroethylene over an 8-hour time-weighted average; however, manual garment transfer operations result in employee exposures which sometimes exceed the peak allowable concentration ($\sim 2,040 \text{ mg/m}^3$) (NIOSH 1980). Table U-1 also lists the ratio of the OSHA standard for perchloroethylene (i.e., 680 mg/m^3) to the estimated perchloroethylene equilibrium concentration in air.

If it is assumed that the difference between the OSHA permissible concentration and the maximum equilibrium concentration of perchloroethylene is due to the dilution effects of general room ventilation and local exhausts, then this ratio can also be expected to apply for actual levels of PCBs in workplace air and the maximum equilibrium concentrations of PCBs that were calculated in Attachment D. Table U-2 lists the expected workplace PCB air concentrations assuming that this relationship is valid.

U.4. Estimation of Annual Individual Worker Exposure to Evaporated PCBs

Table U-3 lists the estimated annual individual worker exposures for the estimated PCB levels in dry-cleaning establishment workplace air listed in Table U-2.

Table U-2. Maximum Expected Workplace Air Concentrations of Evaporated PCBs in Dry-Cleaning Establishments

| System temperature (°C) | PCB concentration in perchloroethylene (mg/kg) | Maximum PCB concentration at equilibrium ^a (mg/m ³) | Ratio of max. expected air concentration to equilibrium concentration ^b | Max. expected workplace air PCB concentration ^c (mg/m ³) |
|-------------------------|------------------------------------------------|----------------------------------------------------------------------------|------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| 25 | 50 | 1.8 x 10 ⁻⁴ | 5.4 x 10 ⁻³ | 9.7 x 10 ⁻⁷ |
| | 25 | 8.7 x 10 ⁻⁵ | 5.4 x 10 ⁻³ | 4.7 x 10 ⁻⁷ |
| | 2 | 6.8 x 10 ⁻⁶ | 5.4 x 10 ⁻³ | 3.7 x 10 ⁻⁸ |
| 50 | 50 | 2.7 x 10 ⁻³ | 1.4 x 10 ⁻³ | 3.8 x 10 ⁻⁶ |
| | 25 | 1.4 x 10 ⁻³ | 1.4 x 10 ⁻³ | 2.0 x 10 ⁻⁶ |
| | 2 | 1.1 x 10 ⁻⁴ | 1.4 x 10 ⁻³ | 1.5 x 10 ⁻⁷ |
| 75 | 50 | 3.1 x 10 ⁻² | 4.4 x 10 ⁻⁴ | 1.4 x 10 ⁻⁵ |
| | 25 | 1.6 x 10 ⁻² | 4.4 x 10 ⁻⁴ | 7.0 x 10 ⁻⁶ |
| | 2 | 1.2 x 10 ⁻³ | 4.4 x 10 ⁻⁴ | 5.3 x 10 ⁻⁷ |

^aSource: Calculated using data presented in Attachment D (Tables D-1 and D-2) after adjustment to account for the molecular weight of perchloroethylene (see Footnote A to Table D-1).

^bSource: Table U-1.

^cCalculated by multiplying the maximum PCB concentration at equilibrium by the ratio of maximum expected workroom concentration to equilibrium concentration.

Table U-3. Estimated Annual Individual Worker Exposure to Evaporated PCBs

| System temperature (°C) | PCB concentration in perchloroethylene (mg/kg) | Max. expected workplace PCB concentration ^a (mg/m ³) | Annual individual worker exposure ^b (mg/yr) |
|-------------------------|------------------------------------------------|-----------------------------------------------------------------------------|--------------------------------------------------------|
| 25 | 50 | 9.7×10^{-7} | 2.2×10^{-3} |
| | 25 | 4.7×10^{-7} | 1.1×10^{-3} |
| | 2 | 3.7×10^{-8} | 8.5×10^{-5} |
| 50 | 50 | 3.8×10^{-6} | 8.8×10^{-3} |
| | 25 | 2.0×10^{-6} | 4.6×10^{-3} |
| | 2 | 1.5×10^{-7} | 3.5×10^{-4} |
| 75 | 50 | 1.4×10^{-5} | 3.2×10^{-2} |
| | 25 | 7.0×10^{-6} | 1.6×10^{-2} |
| | 2 | 5.3×10^{-7} | 1.2×10^{-3} |

^aSource: Table U-2.

^bCalculated assuming exposure for 40 hours per week, 48 weeks per year, and a breathing rate of 1.2 m³/hr (Versar 1982).

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ATTACHMENT V

Hypothetical Worker Inhalation Exposure to PCBs During Manufacture of Asphalt Roofing Products

V.1. Introduction

The purpose of this attachment is to estimate maximum probable PCB inhalation exposure to workers involved in the manufacture of asphalt roofing products. PCBs are not incidentally produced during this manufacturing process, though they are often found in recycled waste paper used as a source of fiber in the production of felt membranes. PCBs used in carbonless paper until 1971 are still found in waste paper at detectable concentrations.

A source of PCBs in the asphalt roofing industry in the past was recycled waste oil used as viscosity reducers in saturant asphalts. According to the Asphalt Roofing Manufacturers Association (ARMA), the roofing industry now uses only asphalts produced from virgin petroleum oil, eliminating this potential source of PCBs (ARMA 1983).

The processing of PCB-contaminated waste paper, and subsequent incorporation of PCBs into the felt membranes used for shingles and roll goods, involves several steps where workers may be exposed to PCBs in air. Based on process descriptions, the most likely sources of occupational exposure to PCBs in this industry appear to be:

Felt Mill

- The hydropulper, where waste paper is pulped.
- Felt drying operations where sheets of felt are dried at dryer drum temperatures of 275° to 300°F.

Shingle/Roll Manufacturing Line

- Saturator tank where asphalt is applied to sheets of felt by spraying, with temperatures at approximately 480°F.
- Waste handling where drums of condensate oil and product wastes are handled.

The heating operations (felt drying and felt saturation) are probably the most likely sources of fugitive PCB vapors in the asphalt roofing industry. Some PCBs could be expected to evaporate off the felt sheets as they are dried since the drum temperatures approach 300°F and the sheet temperature may reach up to 185°F (ARMA 1981). In the asphalt saturation process, PCBs may volatilize from the felt when contacted with the hot asphalt (ARMA 1983). Though saturates are typically totally enclosed by hoods and vapors are withdrawn by fans to pollution control devices, fugitive emissions may occur if hooding is not properly designed, installed, or operated (USEPA 1982). Saturators may also generate mist from spraying asphalt (USEPA 1982), which could increase potential for worker inhalation exposure to PCBs.

V.2 Estimation of Annual Worker Exposure

ARMA has reported the results of extensive industrial hygiene sampling conducted at two felt mills and four roofing plants (ARMA 1983). Personal and area-wide monitoring for PCB vapors was performed to determine potential worker exposure at various plant locations, and for various job categories. Only 2 of 17 area samples with sample durations of four or more hours collected in the areas with potential for worker exposure (two areas in the felt mill and four areas in the roofing plants) showed detectable levels of PCBs. Only 8 of 40 personal samples with sample durations of four or more hours showed detectable PCB levels.

These monitoring data are used here as the basis for calculating hypothetical PCB inhalation exposure estimates for workers in those locations/job classifications. Table V-1 presents the job titles (for personal monitoring) and locations (for area samples), and PCB concentrations in air reported by ARMA. Also presented are hypothetical worker annual exposures to PCBs based on the reported concentrations.

The annual exposure estimates are based on assumptions that a worker is exposed for 40 hours per week, 48 weeks per year, to the given concentration of PCBs. A breathing rate of 1.2 m³/hr is assumed (Versar 1982).

Table V-1. PCB Concentrations in Air and Estimated Annual Exposures to Workers in Asphalt Roofing Manufacturing Plants

| Job title/ location | Sample type ^a | Number of samples ^b | Number of times detected | PCB air concentration (mg/m ³) | | | Estimated annual exposure ^d (mg/yr) | | |
|----------------------------------------------------|-----------------------------|-----------------------------------|-----------------------------|--------------------------------------------|-------------------|---------|------------------------------------------------|------|------|
| | | | | min | mean ^c | max | min | mean | max |
| <u>Felt mill</u> | | | | | | | | | |
| Stock preparation | | | | | | | | | |
| - helper | P | 2 | 2 | 0.0005 | 0.0006 | 0.0006 | 1.2 | 1.2 | 1.4 |
| - laborer | P | 1 | 0 | <0.0005 | <0.0005 | <0.0005 | <1.2 | <1.2 | <1.2 |
| - hydropulper | A | 3 | 1 | <0.0005 | <0.0016 | 0.0028 | <1.2 | <3.7 | 6.4 |
| Manufacturing | | | | | | | | | |
| - machine tender | P | 2 | 2 | 0.0006 | 0.0007 | 0.0008 | 1.4 | 1.6 | 1.8 |
| - mill supervisor | P | 1 | 1 | 0.0007 | 0.0007 | 0.0007 | 1.6 | 1.6 | 1.6 |
| - press rolls | A | 1 | 1 | 0.0008 | 0.0008 | 0.0008 | 1.8 | 1.8 | 1.8 |
| Packaging | | | | | | | | | |
| - inspector | P | 1 | 1 | 0.0006 | 0.0006 | 0.0006 | 1.4 | 1.4 | 1.4 |
| <u>Shingle/roll manufacturing</u> | | | | | | | | | |
| Manufacturing | | | | | | | | | |
| - dry felt tender | P | 7 | 0 | <0.0004 | <0.0006 | <0.0012 | <0.92 | <1.4 | <2.8 |
| - saturator/ coater/surfacing/ tape operator | P | 18 | 1 | <0.0004 | <0.0007 | 0.0018 | <0.92 | <1.6 | 4.1 |
| - saturator/water/ surfacing/tape | A | 9 | 0 | <0.0005 | <0.0008 | <0.0013 | <1.2 | <1.8 | <3.0 |
| - supervisor | P | 2 | 0 | <0.0006 | <0.0008 | <0.0010 | <1.4 | <1.8 | <2.3 |

Table V-1. (continued)

| Job title/ location | Sample type ^a | Number of samples ^b | Number of times detected | PCB air concentration (mg/m ³) | | Estimated annual exposure ^d (mg/yr) | | | |
|----------------------------------------|-----------------------------|-----------------------------------|-----------------------------|--------------------------------------------|-------------------|------------------------------------------------|-------|------|------|
| | | | | min | mean ^c | max | min | mean | max |
| Packaging - roll winder/ wrapper | P | 2 | 0 | <0.0005 | <0.0005 | <0.0005 | <1.2 | <1.2 | <1.2 |
| Stillyard - still operator | P | 4 | 1 | <0.0001 | <0.0009 | <0.0013 | <0.23 | <2.1 | 3.0 |
| Waste storage | A | 4 | 0 | <0.0004 | <0.0006 | <0.0007 | <0.92 | <1.4 | <1.6 |

^aP = personal sample

A = area sample

^bNumber of samples of four or more hours duration (ARMA 1983).^cMean values were calculated by assigning the detection limit as the air concentration for all "not detected" samples.^dCalculated assuming exposure with no use of respirators for 40 hours per week, 48 weeks per year, and a breathing rate of 1.2 m³/hr (Versar 1982).

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ATTACHMENT W

Hypothetical Worker Exposure to PCBs During Paper Manufacturing Operations Using Wastepaper as a Raw Material

W.1 Introduction

The purpose of this attachment is to estimate maximum probable exposure of workers to PCBs via inhalation during the manufacture of paper and paper products using wastepaper as a raw material. Although PCBs are not expected to be incidentally generated during paper manufacturing operations, they may enter the paper-making process via three routes: (1) as Aroclor PCBs in office paper used as wastepaper furnish; (2) as incidentally produced PCBs associated with diarylide and phthalocyanine pigments used as printing inks on wastepaper furnish; and (3) in the intake water used for paper manufacturing operations (API 1981).

W.2 Sources of Process Contamination

W.2.1. Office Wastepaper

Of the three possible routes of PCB entry into the papermaking process, the most significant in terms of magnitude of process contamination appears to be carbonless copy paper (USEPA 1977, API 1981, USEPA 1982a). Aroclor 1242 was used as an ink solvent in carbonless copy paper during the period from 1957 to 1971. Aroclor 1242 and the ink were encapsulated in gelatin-gum arabic microspheres which would rupture under the application of pressure (as from a pen or pencil) and release the ink and PCBs. Although production of PCB-containing copy paper was discontinued in 1971, approximately 600,000 kkg of this paper was produced (PCB content was approximately 3.4 percent by weight) (USEPA 1977), and some of this potentially recycleable paper still remains in

business and government files. In addition, because of the persistent nature of PCBs and their affinity for paper, previous recycling of this copy paper appears to have resulted, to some extent, in PCB contamination of many paper products manufactured using wastepaper furnish (USEPA 1977, API 1981). This paper will, in turn, reintroduce PCBs into a paper mill when and if it is recycled.

Few data are available concerning current levels of PCBs in wastepaper furnish. API (1981) reports that the average PCB concentration in 14 samples of wastepaper furnish at one mill during 1979 and 1980 was 12 ppm (median of 2.5 ppm; maximum of 130 ppm). API (1981) also reports that 99.5 percent of 3062 samples (1981 testing program) of paper/paperboard made from wastepaper contain less than 5 ppm of PCBs.

W.2.2 Printing Ink

PCBs are known to be incidentally produced during the manufacture of diarylide and phthalocyanine pigments which are extensively used in printing inks. During 1982, PCB concentrations in these pigments were reported to be typically less than 50 ppm (DCMA 1982). Thus, wastepaper furnish containing these pigments could introduce PCBs into the papermaking process.

If PCBs are assumed to be present in printing ink pigments at 50 ppm and the same assumptions regarding pigment levels in ink and ink usage ratio are made here as are made in Attachment CC of this report, then maximum probable PCB levels in newspapers and magazines (i.e., potential wastepaper furnish) would be 45 ppb and 190 ppb, respectively.

W.2.3 Intake Water

An EPA study of PCB involvement in the paper industry (USEPA 1977) determined that 0.1 ug/l was a representative value for PCB concentration in the intake waters of paper mills. This value was derived from EPA regional PCB monitoring studies, STORET data, and data supplied by the Institute of Paper Chemistry.

W.3 Distribution of PCBs During Paper Manufacturing

The manufacture of paper products from wastepaper involves a deinking or ink stripping step followed by the three standard paper manufacturing processes: pulping, bleaching, and papermaking (USEPA 1982a). Because of their relative affinity for paper, most PCBs released from the wastepaper during stripping and pulping are expected to sorb to the paper fibers rather than solubilizing and entering wastewater during sheet forming operations (USEPA 1977). Bleaching of the pulp is not expected to affect any PCBs present. Thus, most of the PCBs entering with the wastepaper are expected to become incorporated into the product (USEPA 1977, USEPA 1982a).

During paper drying operations, the vaporization of excess water is expected to co-distill free (i.e., not encapsulated within microspheres) PCBs. The microspheres are considered essentially stable under conditions typically encountered during papermaking (USEPA 1977). Evaporative emission of PCBs during paper drying is considered to be the primary source of air emissions during the entire paper manufacturing operation (USEPA 1977).

W.4 Estimation of Hypothetical PCB Air Concentrations and Annual Worker Exposures

W.4.1 Basic Assumptions

Monitoring data of PCBs in the workplace air of plants manufacturing paper from recycled wastepaper are not available. In lieu of monitoring data, worst-case hypothetical air levels can be estimated using the following assumptions:

- The primary potential source of PCB emissions to workroom air is the paper drying operation (USEPA 1977).
- Emissions from the paper dryer are not vented out of the workplace. (In fact, most dryers are covered with hoods for collection and removal of the water vapor (Baum et al. 1981).)

- The paper is assumed to be manufactured entirely with wastepaper rather than a mix of wastepaper and virgin pulp.
- All PCBs present in the wastepaper remain with the paper pulp, and all PCBs present in the intake water become associated with the paper pulp.
- Any PCBs present in the pulp are not reacted with the paper fibers or physically bound within microspheres and are therefore free to evaporate.

W.4.2 Estimation of PCB Concentrations in Paper Sheet Pulp

The water content of the paper pulp entering a paper dryer is typically 1.2 to 1.9 parts of water per part of fiber (Baum et al. 1981). For this exposure scenario, it will be assumed that the water content is 1.5 parts of water per part of fiber. Thus, any PCBs entering the papermaking process in wastepaper will be diluted by a factor of 2.5 in the wet paper sheet pulp: $\frac{(1.5 \text{ parts of water}) + (1.0 \text{ part of fiber})}{(1.0 \text{ part of fiber})}$.

Paper mills use an average of 86 liters of water to produce one kg of paper (USEPA 1982b). Thus, assuming a water content of 1.5 parts of water to one part of fiber in the paper sheet pulp, any PCBs present in the intake waters could be concentrated in the pulp by a factor of 34.4:

$$\frac{1 \text{ ug PCB}}{1 \text{ liter water}} \times \frac{1 \text{ liter water}}{1 \text{ kg water}} \times \frac{86 \text{ kg water}}{1 \text{ kg paper}} \times \frac{1 \text{ kg paper}}{2.5 \text{ kg pulp}} \times \frac{34.4 \times 1 \text{ ug PCB}}{\text{kg pulp}}$$

W.4.3 Estimation of PCB Evaporation Rates

At 100°C (i.e., the approximate paper drying temperature), the vapor pressure of pure Aroclor 1242 is 5×10^{-1} torr, and its evaporation rate is $0.338 \text{ mg/cm}^2/\text{hr}$ (Hutzinger et al. 1974). If it is assumed that the partial pressure of PCBs above the paper sheet pulp during drying can be estimated using Raoult's Law* and that there is a direct

*Although Raoult's Law applies to miscible liquids and PCBs are relatively insoluble in pure water (0.23 mg/l for Aroclor 1242 at 25°C (USEPA 1981)), Raoult's Law will be applied here because (1) the expected PCB levels in the pulp are very low (in the low mg/l range) and (2) the elevated temperatures during drying should increase the water solubility of PCBs.

proportionality between PCB partial pressures and evaporation rates at different PCB pulp concentrations, then PCB evaporation rates from the paper pulp can be estimated for different PCB concentrations in the pulp. This is a worst-case set of assumptions because, in general, PCBs will be sorbed to the paper fibers rather than being solubilized in the water and left free to evaporate. Table W-1 lists the estimated PCB evaporation rates for several hypothetical pulp concentrations of PCBs.

W.4.4 Estimation of PCB Air Concentrations and Annual Worker Exposure

Based on the evaporation rates estimated in Table W-1, the maximum probable levels of PCBs in workroom air can be estimated using the following conservative assumptions:

- The room in which the paper drying operation is performed has a low ceiling height of 10 ft (or 3.0 m).
- The general ventilation in the room is assumed to be only four air changes per hour.
- It is assumed that the ratio of the exposed surface area of the drying paper to the floor surface area of the room is 0.3:1. Therefore, assuming a floor surface area of 100 m², the exposed surface area is 30 m².

Table W-2 lists the estimated PCB air concentrations for the various assumed PCB concentrations in the pulp. Table W-2 also lists the estimated annual individual worker exposures, assuming continuous exposure (i.e., 40 hours per week) to the listed concentrations.

Table W-1. Estimated Evaporation Rates of Aroclor 1242
from Paper Pulp at 100°C

| PCB concentration in wastepaper/intake water ^a (mg/kg or mg/l) | PCB concentration in paper sheet pulp ^b (mg/kg) | Partial pressure of Aroclor 1242 above pulp ^c (torr) | Evaporation rate ^d (mg/cm ² /hr) |
|---------------------------------------------------------------------------------|------------------------------------------------------------------|-----------------------------------------------------------------------|--------------------------------------------------------------|
| 12 | 4.8 | 2.4×10^{-6} | 1.6×10^{-6} |
| 5.0 | 2.0 | 1.0×10^{-6} | 6.8×10^{-7} |
| 2.5 | 1.0 | 5.0×10^{-7} | 3.4×10^{-7} |
| 0.19 | 0.076 | 3.8×10^{-8} | 2.6×10^{-8} |
| 0.045 | 0.018 | 9.0×10^{-9} | 6.1×10^{-9} |
| 0.0001 | 0.0034 | 1.7×10^{-9} | 1.1×10^{-9} |

^aThe listed concentrations correspond to:

- 12 mg/kg = mean concentration of PCBs in wastepaper furnish (API 1981).
- 5.0 mg/kg = PCB concentration exceeded in only 0.5 percent of 3062 samples of recycled paper/paperboard in 1981 (API 1981).
- 2.5 mg/kg = median concentration of PCBs in wastepaper furnish (API 1981).
- 0.19 mg/kg = expected PCB concentration in magazine wastepaper (see Section W.2.2).
- 0.045 mg/kg = expected PCB concentration in newsprint wastepaper (see Section W.2.2).
- 0.0001 mg/l = representative PCB concentration in paper mill intake water (USEPA 1977).

^bCalculated using assumptions in Section W.4.2.

^cPartial pressures above the pulp were calculated using Raoult's Law (see Section W.4.3 and Attachment D for details).

^dIt is assumed that the evaporation rates of Aroclor 1242 at different concentrations in the pulp are directly proportional to the ratio of the vapor pressures at the corresponding concentrations. Thus, the evaporation rate is calculated as follows.

$$\text{evaporation rate at concentration C} = \frac{\text{partial pressure at concentration C}}{\text{partial pressure of pure Aroclor 1242}} \times \left(\text{evaporation rate of pure Aroclor 1242} \right)$$

where, the partial pressure and evaporation rate of pure Aroclor 1242 are
0.5 torr and 0.338 mg/cm²/hr, respectively, at 100°C (Hutzinger et al. 1974).

Table W-2. Estimated PCB Air Concentrations and Annual Individual Worker Exposures

| PCB concentration in wastepaper/intake water ^a (mg/kg or mg/l) | Maximum PCB air concentration ^b (mg/m ³) | Annual individual worker exposure ^c (mg/yr) |
|---------------------------------------------------------------------------------|-----------------------------------------------------------------------|--------------------------------------------------------------|
| 12 | 4.0×10^{-4} | 9.2×10^{-1} |
| 5.0 | 1.7×10^{-4} | 3.9×10^{-1} |
| 2.5 | 8.5×10^{-5} | 2.0×10^{-1} |
| 0.19 | 6.5×10^{-6} | 1.5×10^{-2} |
| 0.045 | 1.5×10^{-6} | 3.4×10^{-3} |
| 0.0001 | 2.7×10^{-7} | 6.3×10^{-4} |

^aSee Table W-1 for source of these concentrations.

^bPCB air concentrations were calculated as follows using the assumptions listed in Section W.4.4.

$$\text{PCB air concentration} = \frac{(\text{PCB evaporation rate}) \times (\text{exposed surface area}) \times (10^4 \text{ cm}^2/\text{m}^2)}{(\text{room air volume of } 300 \text{ m}^3) \times (4 \text{ air changes/hr})}$$

^cAnnual exposures were calculated assuming exposure to the listed concentration for 40 hours per week, 48 weeks per year, and a breathing rate of 1.2 m³ per hour (Versar 1982).

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ATTACHMENT X

Hypothetical Worker Exposure to PCBs From Recycling of Contaminated Industrial Waste Oils

X.1 Introduction

The purpose of this attachment is to describe the waste oil recycling system and to estimate maximum probable worker exposure to PCBs where contaminated waste oils are industrially or commercially recycled. The PCBs of concern in this exposure scenario are "commercially-produced PCBs" (Aroclors) as opposed to those that are generated inadvertently. For more information on occurrence of Aroclors in industrial oils, see the Exposure Assessment for Hydraulic and Heat Transfer Authorized Uses (Appendix D of this report).

X.2 Background

Approximately 35 percent of all waste oils originate in industry (Bider et al. 1983). Other waste oils characterized as automotive oils are not considered in this exposure scenario. Many end uses of industrial waste oil involve reprocessing or reusing the oils in occupational situations where worker exposure to a contaminant could occur. Figure X-1 illustrates the relative significance of these end uses according to 1982 figures. This information shows that a vast majority of the industrial waste oil generated is collected for rerefining or reprocessing (differing only in level of treatment). Table X-1 sums the overall percentages of waste oil per use/disposal category depicted in Figure X-1.

X.2.1 Rerefining of Waste Oil Into Lube Oil

Lube oil production from industrial waste oil requires the employment of one of the rerefining processes listed below:

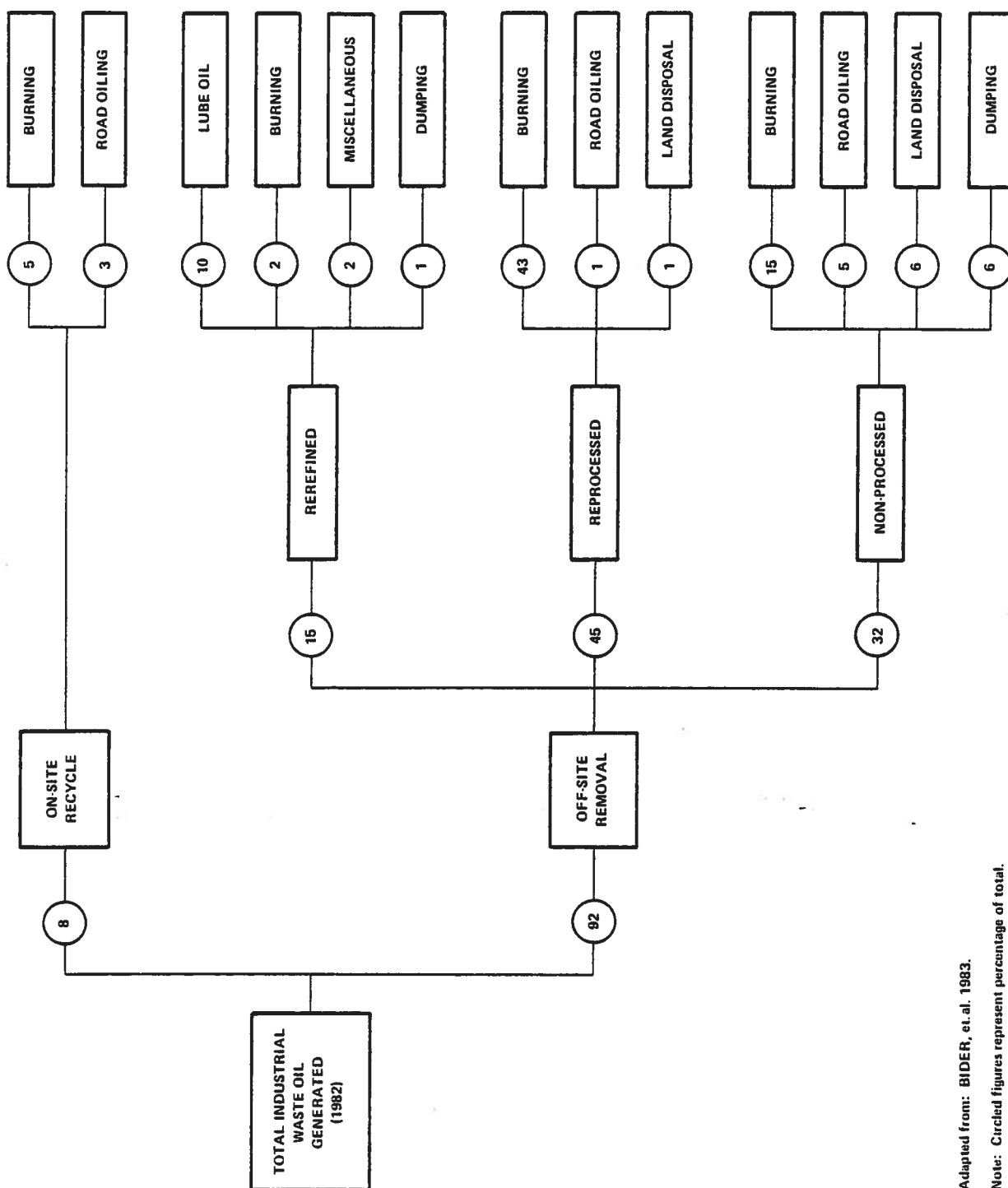


FIGURE X-1

Adapted from: BIDER, et al. 1983.
 Note: Circled figures represent percentage of total.

Table X-1. Industrial Waste Oil Use/Disposal - 1982

| End use | Percent |
|---------------|----------|
| Reuse: | |
| Lube oil | 10 |
| Road oiling | 9 |
| Miscellaneous | 2 |
| Disposal: | |
| Burning | 65 |
| Land disposal | 7 |
| Dumping | <u>7</u> |
| Total | 100 |

(From Figure X-1).

- Acid/clay Treatment.
- Phillips Rerefining Oil Process (PROP).
- Distillation/Clay Treatment Process.
- Distillation/Hydrogen Treating Process.
- Solvent/Distillation Process.

Each of these processes includes steps that clean and recondition the oil to specifications comparable to new lube oil products. Steps common to most of the processes listed above include: (1) removal of solid particles by settling, centrifuging, or filtering; (2) neutralization of acidic components with clay or alkalies, and removal of resulting soaps by washing; (3) heating-distillation to remove volatile solvents, gasoline, and water; (4) clay contacting to remove oxygenated components and spent additives or for decolorization; (5) aeration and use of biocides to reduce bacterial levels; and (6) replenishment of additives (Becker 1982).

Detailed process descriptions (Hess 1979) reveal that the highest process unit operation temperature is 350°C during hydrotreating, a finishing step when hydrogen reacts with oxygen, nitrogen-containing impurities, and unsaturates. The process most common in commercial rerefinerries is the PROP process. Phillips claims that (1) the process recovers over 90 percent of the waste oil, (2) the filter cake produced during demetallization (about 100 pounds/hour for a 2-million-gallon /year rerefining plant) can be disposed of safely in landfills, (3) in some areas, resulting wastewater can be sent to municipal disposal systems without pretreatment, and (4) the metals content of the rerefined oil is less than 10 ppm. The PROP process also produces a side stream of heavy gasoline (in the diesel-fuel range) that can be sold (Berry 1979).

X.2.2 Use of Waste Oil for Road Oiling

Road oiling is currently the most controversial use/disposal category for industrial waste oil. Most experts agree (Bider et al. 1983) that a shift in waste oil use from road oiling to waste oil burning will occur

in the near future for several reasons: (1) the sensational media coverage regarding recent dioxin contamination via road oiling, (2) stricter state and local environmental regulations, and (3) the increased price of fuel. In any case, occupational exposure to PCBs in waste oil used as a dust suppressant in road oiling operations will not be estimated in this exposure scenario because of the illegality of PCB presence in road oiling material.*

X.2.3 Burning of Waste Oil

Burning, with or without pretreatment, represents the greatest end use for industrial waste oil. Waste oil is most commonly burned in steam boilers, usually blended with virgin fuels. Cement kilns, asphalt plants, industrial incinerators, and diesel engines also utilize waste oil mixtures as acceptable fuel. In addition, there is a growing market for small "waste oil heaters" of up to about 0.6 million Btu/hr (4.3 gal/hr) capacity for home and small commercial use, including service stations (RECON 1980).

Content of PCBs in waste oil fuel is regulated by TSCA in the following manner:

- For PCB liquids containing 500 ppm PCB or greater, disposal is permitted only in EPA-approved incinerators.
- For PCB liquids containing 50-500 ppm, disposal is permitted in EPA-approved incinerators, in high efficiency boilers rated at a minimum of 50 million Btu/hr (under rigidly controlled combustion conditions), and in EPA-approved chemical waste landfills (approved for PCBs).
- Liquids containing less than 50 ppm are not considered PCBs (unless dilution was involved), and their burning is not regulated.

*The use of waste oil that contains any detectable concentration of PCB as a sealant, coating, or dust control agent is prohibited. Prohibited uses include, but are not limited to, road oiling, general dust control, use as a pesticide or herbicide carrier, and use as a rust preventative on pipes (40 CFR 761).

Accordingly, only those liquid wastes containing less than 50 ppm PCBs would pose an exposure potential via burning. This would almost exclusively be an ambient exposure concern.

Hypothetical ambient PCB air levels resulting from incineration of PCB-containing wastes (with less than 50 ppm PCBs) have already been addressed in Attachment B of this volume. The model incinerator with 1,300 kg waste/hr capacity used to predict ambient air levels of PCBs should reflect the greatest probable source emission from the waste oil burning methods described previously.

X.2.4 Land Disposal of Waste Oil

Land disposal of waste oil is subject to the TSCA regulations for PCB-containing liquid wastes cited previously. As with burning, the primary concern with land disposal is the potential ambient exposure (via groundwater) from landfilling and landfarming waste oils containing less than 50 ppm PCBs.

Hypothetical PCB levels in groundwater resulting from landfilling of PCB-containing waste (with less than 50 ppm PCBs) have already been addressed in Attachment C of this volume. The PCB loading rate estimated for a model chemical manufacturing plant's three-acre landfill should reflect the greatest probable loading from a commercial landfill servicing PCB-containing waste oil disposal.

X.2.5 Dumping of Waste Oil

Dumping of PCB-containing liquid wastes describes uncontrolled, unconventional, and often illegal disposal activity. When this occurs with waste oils containing PCBs at concentrations greater than 50 ppm, it is in violation of TSCA regulation. Unfortunately, this unassessable disposal category leads to the greatest environmental impact.

X.3 Hypothetical Worker Exposure to PCBs During Rerefining Operations

X.3.1 Introduction

Worker exposure to PCBs in waste oil rerefining/reprocessing plants producing lube oils and other reusable by-products may involve both inhalation exposure from in-plant fugitive emissions and dermal exposure from transfer operations and maintenance of some process vessels.

X.3.2 Estimation of Air Concentrations of PCBs and Potential Worker Exposure

Because no monitoring data of PCBs in the workplace air of waste oil rerefining plants are available, maximum probable air levels of PCBs will be estimated based on hypothetical correlation between monitored levels of naphthalenes in petroleum refinery air and possible PCB air levels in waste oil rerefinerries.

This hypothetical correlation is based on the following assumptions:

- Petroleum refineries and waste oil rerefinerries are similar enough in terms of types and relative numbers of potential fugitive emission sources (i.e., valves, flanges, seals) and operational characteristics (i.e., workshifts, worker proximity to equipment, protective equipment used) to support an exposure correlation.
- Air concentrations of naphthalenes in petroleum refineries are due solely to release from the crude oil feed stock, not from any internal process or machinery operation that could generate and release PAHs (e.g., internal combustion engine exhaust).
- If both PCBs and naphthalenes were present at equal concentrations in the oil, then workplace air levels of PCBs would be no greater than levels of naphthalenes in air. This is supported by the fact that the vapor pressure of Aroclor 1242 (4×10^{-4} torr at 25°C) is almost two orders of magnitude less than that of naphthalene (8.7×10^{-2} torr at 25°C) (Hutzinger et al. 1974, USEPA 1981).

If it is further assumed that the ratio of PCB levels in air to levels of naphthalene in air is roughly similar to the ratio of their levels in the oil, then maximum levels of PCBs in air can be estimated for various PCB concentrations in the oil if naphthalene levels in air and oil are known. This relationship is described in Equation X-1.

$$A = \frac{B}{C} \times D \quad (X-1)$$

where

A = the PCB concentration in air (mg/m³)

B = the PCB concentration in oil

C = the concentration of naphthalenes in oil (assumed to be 1.3 percent by weight (Korte and Boedefeld 1978))

D = the concentration of naphthalenes in air (mg/m³).

Table X-2 lists the levels of naphthalenes measured during an in-depth NIOSH study of a petroleum refinery (Enviro Control, Inc. 1980). The table reports the results of 19 workshift (i.e., 7 to 8 hours) area samples and 24 workshift personal samples.

Table X-3 lists the estimated PCB levels in workplace air for various PCB concentrations in the oil. These estimated levels were calculated using Equation X-1. Table X-3 also lists the potential annual PCB exposure for a worker exposed to these levels.

Table X-2. Measured Levels of Napthalenes in
Petroleum Refinery Workplace Air^a

| Type of sample | No. of samples collected | No. of times detected | Concentration ^b (mg/m ³) | | |
|-------------------|-----------------------------|--------------------------|-------------------------------------------------|-----------------------|-----------------------|
| | | | min. | mean | max. |
| Area | 19 | 18 | ND | 1.00×10^{-2} | 3.94×10^{-2} |
| Personal | 24 | 24 | 3.93×10^{-3} | 2.18×10^{-2} | 6.69×10^{-2} |

^aAll data obtained from Enviro Control, Inc. (1980).

^bConcentrations represent the sum of the reported concentrations for napthalene, 1-methylnaphthalene, and 2-methylnaphthalene.

Table X-3. Estimated PCB Air Concentrations and Worker Exposures

| PCB concentration in waste oil ^a (mg/kg) | PCB concentration in workplace air ^b (mg/m ³) | Annual individual worker exposure ^c (mg/yr) |
|-----------------------------------------------------------|----------------------------------------------------------------------------|--------------------------------------------------------------|
| 50 | 8.4×10^{-5} | 1.9×10^{-1} |
| 25 | 4.2×10^{-5} | 9.7×10^{-2} |
| 2 | 3.4×10^{-6} | 7.8×10^{-3} |

^aThese are assumed PCB concentrations in the waste oil.

^bCalculated using Equation X-1 and assuming that the naphthalene concentration in air is 2.18×10^{-2} mg/m³ (i.e., the average of the personal sample results as listed in Table X-2).

^cAnnual individual worker exposure assumes exposure to the estimated PCB concentration for 40 hours per week for 48 weeks per year. A breathing rate of 1.2 m³/hr, corresponding to the mean of the average breathing rates for medium activity and low activity stress levels (Versar 1982), was assumed.

X.3.3 Estimation of Potential Dermal Exposure to Workers

Estimation of the maximum probable dermal exposures to PCBs in waste oil rerefining/reprocessing plants is based on the findings of Attachment Y, Hypothetical Dermal Exposures to PCBs in the Occupational Environment. The final exposure values have been slightly modified reflecting a film thickness (retained on the hands following immersion and partial wipe) more reflective of waste oil viscosity (0.0016 cm; Versar 1983). Though Attachment Y specifically addresses exposure to incidentally produced PCBs, the analysis also applies for PCBs introduced in the feed stock (i.e., waste oil), Table X-4 summarizes the estimated dermal exposures to PCBs during two worker activities in waste oil rerefinement.

Table X-4. Estimated Dermal Exposures to PCBs

| Exposure scenario | Physical form of the chemical | Frequency (events/yr) | Annual dermal exposure (mg/yr) for PCB concentrations | | |
|--------------------------------------------|----------------------------------|--------------------------|----------------------------------------------------------|----------|---------|
| | | | 50 mg/kg | 25 mg/kg | 2 mg/kg |
| <u>Transfer and Handling Operations</u> | | | | | |
| ● Loading/unloading liquid | liquid | 96 | 11.0 | 5.3 | 0.43 |
| <u>Sampling and Maintenance Operations</u> | | | | | |
| ● Removing still bottoms | liquid | 48 | 5.3 | 2.7 | 0.21 |

Source: Adapted from Attachment Y.

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Versar. 1982. Methodology for assessing exposure to toxic chemicals in the ambient environment. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances. Contract No. 68-01-6271.

Versar. 1983. Exposure assessment for retention of chemical liquids on hands. Preliminary draft report. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances. Contract No. 68-01-6271.

ATTACHMENT Y

Hypothetical Dermal Exposures to PCBs in the Occupational Environment

Y.1. Introduction

The purpose of this attachment is to estimate maximum hypothetical dermal exposures to PCBs during the handling and processing of chemicals and products potentially containing incidentally produced PCBs. All exposures estimated in this attachment are based on the worst case assumption that no protective clothing or equipment is worn.

Y.2. Estimation of Annual Dermal Exposures

Annual dermal exposures to PCBs resulting from use of a specific chemical or product can be estimated using Equation Y-1.

$$\begin{array}{lclclcl} \text{Amount PCBs} & & \text{PCBs available} & & \text{Frequency of} & & \text{Absorption} & & \\ \text{absorbed} & = & \text{for absorbtion} & \times & \text{exposure} & \times & \text{rate} & & \\ (\text{mg/yr}) & & (\text{mg/event}) & & (\text{events/yr}) & & (\%) & & (\text{Y-1}) \end{array}$$

where, for liquids

$$\text{PCBs available for absorption (mg/event)} = T \times L \times C \times S \quad (\text{Y-2})$$

T = liquid film thickness on skin (cm)

L = density of liquid (mg/cm³)

C = PCB concentration in the liquid (kg/kg)

S = skin area exposed per event (cm²/event).

and, for dusts

$$\text{PCBs available for absorption (mg/event)} = M \times C \times S \quad (\text{Y-3})$$

where

$M = 2.77 \text{ mg/cm}^2$ (i.e., the maximum mass of a dust that can adhere to one cm^2 of skin) (Versar 1982)

$C = \text{PCB concentration in dust (kg/kg)}$

$S = \text{skin area exposed per event (cm}^2/\text{event)}$.

As can be seen from Equations Y-1, Y-2, and Y-3, a large number of factors influence the extent of dermal absorption of PCBs. The multitude of uses for which the large number of chemicals hypothetically containing incidentally produced PCBs can be employed present virtually limitless combinations of these factors. It was therefore necessary to assign static values to several of the factors as reasonable, conservative estimates of the upper limit in actual range in possible values.

- T (liquid film thickness) assumed to be 0.0018 cm. This is the average of the measured film thicknesses of five solutions on the skin after immersion of hands into the solution followed by a partial wipe with a rag: mineral oil, cooking oil, bath oil, 50% bath oil/50% water, and water (Versar 1983).
- L (density of liquid) assumed to be $1.6 \times 10^3 \text{ mg/cm}^3$.
- S (skin area exposed) assumed to be the entire surface area of both hands (i.e., 870 cm^2).
- Absorption = 100 percent (see discussion in Volume I, Section 3.3.3(1) of this report).

Table Y-1 presents estimated annual dermal exposures to PCBs during generic operations that could result in dermal exposures: transfer and handling operations, processing operations, and sampling and maintenance operations. Frequency of exposure was hypothesized for each operation. Dermal exposures were estimated for three hypothetical PCB concentrations in the chemical or product: 50 mg/kg, 25 mg/kg, and 2 mg/kg.

Table Y-1. Hypothetical Estimated Dermal Exposures to PCBs^a

| Exposure scenario | Physical form of the chemical | Frequency (events/yr) | Annual dermal exposure (mg/yr) for PCB concentrations | |
|--------------------------------------------------------|----------------------------------|--------------------------|----------------------------------------------------------|-------------------------|
| | | | 50 mg/kg | 25 mg/kg 2 mg/kg |
| <u>Transfer and Handling Operations</u> | | | | |
| ● Loading/unloading liquid | liquid | 96 | 12 | 6.0 0.48 |
| ● Loading/unloading powder | dust | 96 | 12 | 5.8 0.46 |
| <u>Processing Operations</u> | | | | |
| ● Closed process operations | liquid | 48 | 6.0 | 3.0 0.24 |
| ● Open surface tank operations | liquid | 240 | 30 | 15 1.2 |
| ● Spray painting operations | liquid | 240 | 30 | 15 1.2 |
| ● Grain fumigation operations | liquid | 240 | 30 | 15 1.2 |
| ● Air-blast pesticide spraying operations ^b | liquid | - | 0.82 | 0.41 0.033 |
| ● Non-spray coating operations | liquid | 240 | 30 | 15 1.2 |
| ● Product formulation operations | liquid dust | 96 96 | 12 12 | 6.0 5.8 0.48 0.46 |
| ● Product fabrication operations | | | | |
| ● Metalworking operations | liquid | 240 | 30 | 15 1.2 |
| ● Newspaper production | dust | 240 | 30 | 15 1.2 |
| ● Plastics processing | dust | 240 | 30 | 15 1.2 |
| ● Dry cleaning of garments | liquid | 240 | 30 | 15 1.2 |

Table Y-1. (continued)

| Exposure scenario | Physical form of the chemical | Frequency (events/yr) | Annual dermal exposure (mg/yr) for PCB concentrations | | |
|--------------------------------------------|----------------------------------|--------------------------|----------------------------------------------------------|--------------|----------------|
| | | | 50 mg/kg | 25 mg/kg | 2 mg/kg |
| <u>Sampling and Maintenance Operations</u> | | | | | |
| ● On-line repair of leaking equipment | liquid | 4 | 0.50 | 0.25 | 0.020 |
| ● Sampling process stream | liquid | 240 | 30 | 15 | 1.2 |
| ● Cleaning equipment | liquid | 48 | 6.0 | 3.0 | 0.24 |
| ● Off-line repair of equipment | liquid | 24 | 3.0 | 1.5 | 0.12 |
| ● Removing filters | liquid | 48 | 6.0 | 3.0 | 0.24 |
| ● Removing still bottoms | liquid | 48 | 6.0 | 3.0 | 0.24 |
| ● Spill cleanup | liquid dust | 12 12 | 1.5 1.5 | 0.75 0.72 | 0.060 0.058 |

^aEstimated dermal exposures were calculated using Equation Y-1 and the assumptions listed in Section Y-2.

^bAnnual exposures for air-blast pesticide spraying were estimated in Attachment T.

References

Versar. 1982. Priority review level I exposure assessment for 4,4'-Methylenebis(2-chloroaniline)(MOCA). Final report. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances. Contract No. 68-01-6271.

Versar 1983. Exposure assessment for retention of chemical liquids on hands. Preliminary draft report. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances. Contract No. 68-01-6271.

ATTACHMENT Z

Hypothetical Occupational and Consumer Exposure To PCBs in Natural Gas

Z.1. Introduction

PCBs have been detected in gas pipelines, both in a condensate which collects in pools in the pipe and in the gas itself. This attachment examines the potential exposure of employees and consumers to PCBs in gas pipelines.

Z.2. PCB Contamination in the Gas Industry

In 1980, the gas industry had 1,050,000 miles of pipe; 83,200 miles were used for field and gathering operations, 266,900 miles were used for transmission; and 700,100 miles were used for distribution (AGA 1980). A field and gathering system is a network of pipelines transporting natural gas from individual wells to compressor station, processing point, or main trunk pipeline. A transmission system consists of pipelines installed for the purpose of transmitting gas from a source or sources of supply to one or more distribution centers or to one or more large volume customers, or a pipeline installed to interconnect sources of supply. A distribution system is generally mains, services, and equipment which carry or control the supply of gas from the point of local supply to and including the sales meters (AGA 1980).

Gas is moved through the pipelines by compressors. A compressor station is any permanent combination of facilities that supplies the energy to move gas at increased pressures from fields, in transmission lines, between local distribution systems, or into storage. Gate stations are locations where gas changes ownership between parties neither of which is the ultimate consumer (AGA 1980).

The transmission system for natural gas consists of a network of pipes with compressor stations at 50 to 100 mile intervals, isolation

valves at 10 to 30 mile intervals, and metering and regulating stations at delivery points. Operating pressures in transmission lines typically range from 55 to 85 atm (USEPA 1981).

Distribution companies purchase gas from transmission companies and deliver it to customers. Gas is received at a gate station at 8 to 11 atm of pressure, pumped through medium pressure lines at about 3 atm pressure, and delivered to residential and small commercial users at slightly above atmospheric pressure.

Natural gas systems usually experience peak demand during the winter. In periods of low demand, transmission companies often store gas in depleted reservoirs. In periods of peak demand, the gas is compressed and injected into the pipeline at pipeline pressure. Extra compressors may be required to deliver gas from storage and from facilities such as liquid natural gas storage facilities and synthetic natural gas plants and other facilities designed to meet peak demands for natural gas.

PCBs were first identified in gas pipelines in January 1981 when a PCB-containing, oily condensate was found in the gas meters of some residential customers of a Long Island, New York, distribution company. Under the direction of EPA, 33 transmission companies undertook voluntary monitoring of condensate and natural gas to determine PCB concentrations. Twelve companies that found elevated PCB concentrations in condensate continued to supply EPA with monitoring data and developed methods to lower the PCB concentrations. EPA Regional Offices have collected data from distribution companies. PCBs in gas pipelines appear to be concentrated in certain portions of the United States, namely, the Northeast and North Central areas and California. Table Z-1 contains a summary of all the data in the possession of OTS on PCB levels in condensate.

Condensate is a mixture of heavier hydrocarbons and other liquids such as water which condense because the gas is transmitted under pressure. This condensate tends to collect in pools in the pipes,

Table 2-1. PCBs in Condensate in Natural Gas Pipelines

| Description | No. of attempts to collect samples | Number of samples collected by PCB concentration (mg/kg) | | | | | | | | | Maximum concn. (mg/kg) | Volume of condensate collected ^b | |
|------------------------------------|------------------------------------|----------------------------------------------------------|-------|--------|----------|------------|--------------|---------------|---------|---------------|------------------------|---------------------------------------------------------------------------|--|
| | | <25 | 25-50 | 50-100 | >100-500 | >500-1,000 | >1,000-5,000 | >5,000-10,000 | >10,000 | No condensate | | | |
| I. Transmission company condensate | | | | | | | | | | | | | |
| A. Company A | | | | | | | | | | | | | |
| 1. First quarter 1983 | 26 | 9 | 0 | 2 | 4 | 1 | 1 | 0 | 0 | 9 | 4,464 | 1,442 gal. (>500 mg/kg PCBs) | |
| 2. 1982 | 56 | 18 | 0 | 1 | 9 | 2 | 1 | 1 | 1 | 23 | 15,805 | 8,272 gal. (50-500 mg/kg PCBs) | |
| B. Company B | | | | | | | | | | | | | |
| 1. First quarter 1983 | 5 | 0 | 0 | 0 | 3 | 0 | 2 | 0 | 0 | 0 | 1,298 | 1,200 gal. (>500 mg/kg PCBs) | |
| 2. 1982 | 32 | 6 | 5 | 5 | 3 | 3 | 0 | 0 | 0 | 10 | 676 | 1,050 gal. (50-500 mg/kg PCBs) | |
| C. Company C | | | | | | | | | | | | | |
| 1. First quarter 1983 | 31 | 22 | 1 | 0 | 3 | 0 | 4 | 0 | 0 | 1 | 4,680 | 0 gal. (>500 mg/kg PCBs) | |
| 2. 1982 | 88 | 51 | 1 | 3 | 8 | 2 | 4 | 6 | 1 | 12 | 18,600 | 1,625 gal. (50-500 mg/kg PCBs) | |
| D. Company D | | | | | | | | | | | | | |
| 1. First quarter 1983 | 46 | 22 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 34 | No data available. | |
| 2. 1982 | 24 | 10 | 6 | 1 | 3 | 0 | 0 | 0 | 0 | 4 | 150 | No data available. | |
| E. Company E | | | | | | | | | | | | | |
| 1. First quarter 1983 | 109 | 31 | 8 | 12 | 6 | 0 | 1 | 0 | 0 | 51 | 1,684 | 1982 and 1983: 5 oz. (>1,000 mg/kg PCBs) 809 gal. (>500 mg/kg PCBs) | |
| 2. 1982 | 725 | 280 | 69 | 64 | 54 | 9 | 1 | 0 | 0 | 248 | 1,600 | 3,085 gal. (50-500 mg/kg PCBs) | |
| F. Company F | | | | | | | | | | | | | |
| 1. First quarter 1983 | 20 | 4 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 12 | 83 | No data available | |
| 2. 1982 | 26 | 6 | 1 | 7 | 0 | 0 | 0 | 0 | 0 | 12 | 87 | No data available | |

Table 2-1. (continued)

| Description | No. of attempts to collect samples | Number of samples collected by PCB concentration (mg/kg) | | | | | | | | | | Maximum concn. (mg/kg) | Volume of condensate collected ^b |
|-----------------------|------------------------------------|----------------------------------------------------------|-------|---------|----------|------------|--------------|---------------|---------|---------------------------------------|--------|--------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|
| | | <25 | 25-50 | >50-100 | >100-500 | >500-1,000 | >1,000-5,000 | >5,000-10,000 | >10,000 | No condensate found after March 1981. | | | |
| G. Company G | | | | | | | | | | | | | |
| 1. First quarter 1981 | 21 | 7 | 7 | 1 | 2 | 2 | 2 | 0 | 0 | 0 | 1,250 | No condensate found after March 1981. | |
| H. Company H | | | | | | | | | | | | | |
| 1. First quarter 1983 | 14 | 2 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 7 | 126 | 0 gal. (>500 mg/kg PCBs) 715 gal. (50-500 mg/kg PCBs) | |
| 2. 1982 | 29 | 1 | 2 | 9 | 9 | 2 | 2 | 0 | 0 | 4 | 2,300 | <5 oz. (>1,000 mg/kg PCBs) 487 gal. (>500 mg/kg PCBs) 4,464 gal. (50-500 mg/kg PCBs) | |
| I. Company I | | | | | | | | | | | | | |
| 1. First quarter 1983 | 147 | 73 | 15 | 4 | 12 | 8 | 24 | 0 | 1 | 10 | 15,500 | 16 gal. (>10,000 mg/kg PCBs) 5,511 gal. (1,000-5,000 mg/kg PCBs) 2,636 gal. (500-1,000 mg/kg PCBs) 5,109 gal. (50-500 mg/kg PCBs) | |
| 2. 1982 | 112 | 73 | 13 | 5 | 7 | 0 | 11 | 0 | 1 | 2 | 15,500 | 16 gal. (>10,000 mg/kg) (Volume of condensate were reported for only some of the analyzed samples.) | |
| J. Company J | | | | | | | | | | | | | |
| 1. First quarter 1983 | 15 | 6 | 6 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 220 | 0 gal. (>500 mg/kg PCBs) 4,819 gal. (50-500 mg/kg PCBs) | |
| 2. 1982 | 46 | 15 | 5 | 9 | 10 | 4 | 3 | 0 | 0 | 0 | 2,100 | 195 gal. (>500 mg/kg PCBs) 8,753 gal. (50-500 mg/kg PCBs) | |
| K. Company K | | | | | | | | | | | | | |
| 1. First quarter 1983 | 72 | 3 | 2 | 15 | 14 | 4 | 3 | 0 | 0 | 31 | 1,252 | 10,811 gal. (50-500 mg/kg PCBs) | |
| 2. 1982 | 136 | 17 | 6 | 23 | 35 | 4 | 8 | 1 | 0 | 42 | 5,100 | 230 gal. (>500 mg/kg PCBs) 42,597 gal. (50-500 mg/kg PCBs) 15,443 gal. (<50 mg/kg PCBs) | |

Table Z-1. (continued)

| Description | No. of attempts to collect samples | Number of samples collected by PCB concentration (mg/kg) | | | | | | | Maximum concn. (mg/kg) | Volume of condensate collected ^b | |
|------------------------------------------|------------------------------------|----------------------------------------------------------|------------|-------------|-------------|------------|--------------|---------------|------------------------|---------------------------------------------|----------------------------------------------------------------------|
| | | No | | | | | | | | | |
| | | <25 | 25-50 | 50-100 | >100-500 | >500-1,000 | >1,000-5,000 | >5,000-10,000 | | | |
| L. Company L | | | | | | | | | | | |
| 1. First quarter 1983 | 4 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 482 | 8,258 gal. (50-500 mg/kg PCBs) 1,231 gal. (<50 mg/kg PCBs) |
| 2. 1982 | 10 | 3 | 1 | 5 | 1 | 0 | 0 | 0 | 0 | 158 | 10,258 gal. (50-500 mg/kg PCBs) 28,259 gal. (<50 mg/kg PCBs) |
| M. Company M | | | | | | | | | | | |
| 1. First quarter 1983 | 19 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 1 | 11 | 27,700 5 ml. (>10,000 mg/kg PCBs) 2,883 gal. (>500 mg/kg PCBs) |
| 2. 1982 | 28 | 0 | 0 | 0 | 0 | 0 | 4 | 2 | 2 | 20 | 42,394 5 oz. (>10,000 mg/kg PCBs) 2,970 gal. (>500 mg/kg PCBs) |
| N. Totals | | | | | | | | | | | |
| 1. First quarter 1983 | 508 | 172 (33.9%) | 36 (7.1%) | 39 (7.8%) | 47 (9.3%) | 13 (2.6%) | 42 (8.3%) | 0 | 2 | 157 (30.9%) | |
| 2. 1982 | 1,312 | 480 (36.5%) | 109 (8.3%) | 132 (10.1%) | 139 (10.6%) | 26 (2.0%) | 34 (2.6%) | 10 (0.8%) | 5 | 377 (28.7%) | |
| 3. First quarter 1981 | 21 | 7 (33.3%) | 7 (33.3%) | 1 (4.8%) | 2 (9.5%) | 2 (9.5%) | 2 (9.5%) | 0 | 0 | 0 | |
| 4. Total | 1,841 | 659 (35.8%) | 152 (8.3%) | 172 (9.3%) | 188 (10.2%) | 41 (2.2%) | 78 (4.2%) | 10 (0.5%) | 7 | 534 (40.9%) | |
| III. Distribution company condensate | | | | | | | | | | | |
| A. Data collected by EPA Region III 1981 | | | | | | | | | | | |
| | 18 | 14 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 220 No data available |
| B. Data collected by EPA Region V 1981 | | | | | | | | | | | |
| | 27 | 12 | 0 | 2 | 8 | 1 | 4 | 0 | 0 | 0 | 1,855/ 3,000 ^c No data available |

Table Z-1. (continued)

| Description | No. of attempts to collect samples ^a | Number of samples collected by PCB concentration (mg/kg) | | | | | | | | | | Maximum concn. (mg/kg) | Volume of condensate collected ^b |
|------------------------------------------------------------------|-------------------------------------------------|----------------------------------------------------------|-------|--------|---------|-----------|-------------|--------|---------|---------------|-------------------|------------------------|---------------------------------------------|
| | | <25 | 25-50 | 50-100 | 100-500 | 500-1,000 | 1,000-5,000 | >5,000 | >10,000 | No condensate | No data available | | |
| C. New York survey of customers - condensate found in gas meters | 13 | 1 | 0 | 0 | 0 | 0 | 7 | 5 | 0 | 0 | 6,500 | No data available | |

^aThese transmission companies attempted to collect samples of condensate at selected collection points in their systems. In many cases, they found no condensate at the collection points.

^bThe volumes listed do not in every case represent the entire volume of contaminated condensate.

^cThis sample was split and analyzed by two laboratories.

Source: Information voluntarily submitted to EPA by natural gas transmission and distribution companies.

especially at points of pressure change such as gate stations. The condensate may leak from the pipes, and the industry has installed "drip bottles" at points of condensate collection to collect these drips and leaks. Because the condensate may impede the flow of the gas, the industry drains the condensate when necessary. Since 1980, the industry has also drained and disposed of condensate as part of its voluntary PCB remedial program. Several thousand gallons of condensate are often removed at a single collection point.

The sources of PCBs in natural gas pipelines cannot be specifically identified. The two most commonly identified sources are historical ones -- the use of PCBs in lubricating oil for compressors, a practice which was discontinued by 1980, and misting of pipelines with PCBs to prevent corrosion, which occurred in the 1940s and 1950s. EPA is unable to identify with certainty all of the companies that used PCBs. However, many companies that never used PCBs have found high levels of PCBs in their condensate. This suggests either that their pipelines have been contaminated by PCBs received from their suppliers or that there is an unidentified source of PCB contamination.

The data summarized in Table Z-1 suggest that PCBs move through the pipes. The transport mechanisms may be movement of condensate as a liquid or as an aerosol or vapor in the gas stream or a combination of all three. The volumes of condensate and PCB concentrations in condensate collected at a given collection point sometimes vary dramatically over time. Where PCB concentrations in condensate have exceeded 50 mg/kg, companies have attempted to prevent the spread of PCBs by installing devices such as filter/separators to remove the condensate. The data examined by EPA cover too short a time period to determine whether the industry's attempts to reduce PCB levels have been successful.

Table Z-2. Summary of Hypothetical Human Exposures to PCBs in Natural Gas

| Exposure type | Exposure scenario | Estimated individual exposure | | | Duration of exposure (yrs) |
|-------------------------|--------------------------------------------------------------------------------|-----------------------------------|-----------------------------------------|----------------------|----------------------------|
| | | during period of exposure (mg/yr) | lifetime average daily dose (mg/kg/day) | | |
| Occupational inhalation | • Removal of condensate and cleanup of spills--employee exposed 240 days/year. | | | | |
| | - 2 mg/kg | 2.5×10^{-2} | 9.8×10^{-7} | 5.4×10^{-7} | 38.5 |
| | - 25 mg/kg | 3.2×10^{-1} | 1.3×10^{-5} | 6.9×10^{-6} | 38.5 |
| | - 50 mg/kg | 6.7×10^{-1} | 2.6×10^{-5} | 1.4×10^{-5} | 38.5 |
| | • Removal of condensate and cleanup of spills--employee exposed 12 days/yr. | | | | |
| | - 2 mg/kg | 1.3×10^{-3} | 5.1×10^{-8} | 2.8×10^{-8} | 38.5 |
| | - 25 mg/kg | 1.6×10^{-2} | 6.3×10^{-7} | 3.5×10^{-7} | 38.5 |
| | - 50 mg/kg | 3.3×10^{-2} | 1.3×10^{-6} | 7.2×10^{-7} | 38.5 |
| | • Removal of condensate and cleanup of spills--employee exposed 240 days/yr | | | | |
| | - 2 mg/kg | 6.7×10^{-1} | 2.6×10^{-5} | 1.4×10^{-5} | 38.5 |
| Occupational dermal | - 25 mg/kg | 8.4 | 3.3×10^{-4} | 1.8×10^{-4} | 38.5 |
| | - 50 mg/kg | 16.7 | 6.5×10^{-4} | 3.6×10^{-4} | 38.5 |
| | • Removal of condensate and cleanup of spills--employee exposed 12 days/yr | | | | |
| | - 2 mg/kg | 3.3×10^{-2} | 1.3×10^{-6} | 7.2×10^{-7} | 38.5 |
| | - 25 mg/kg | 4.2×10^{-1} | 1.6×10^{-5} | 8.8×10^{-6} | 38.5 |
| | - 50 mg/kg | 8.4×10^{-1} | 3.3×10^{-5} | 1.8×10^{-5} | 38.5 |

Table Z-2. (continued)

| Exposure type | Exposure scenario | Estimated individual exposure | | | Duration of exposure (yrs) |
|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|-----------------------------------------|-----------------------------------------|----------------------------|
| | | during period of exposure (mg/yr) | lifetime average daily dose (mg/kg/day) | lifetime average daily dose (mg/kg/day) | |
| Consumer inhalation | <ul style="list-style-type: none"> PCBs are released into a residence. These exposures are estimated from the following concentrations in the natural gas pipeline: <ul style="list-style-type: none"> - 41 $\mu\text{g}/\text{m}^3$ - 8 $\mu\text{g}/\text{m}^3$ | 0.5 | 2.0x10 ⁻⁵ | 2.0x10 ⁻⁵ | 70 |
| | | 0.1 | 3.8x10 ⁻⁶ | 3.8x10 ⁻⁶ | 70 |
| | <p>These concentrations represent PCBs in natural gas associated with condensate concentrations which in many cases exceeded 1,000 mg/kg. If PCBs in condensate are limited to 50 mg/kg, concentrations in natural gas and exposures should be much lower</p> | | | | |

Z.3. Occupational Exposure to PCBs in Gas Pipelines

There are two routes by which employees may be exposed -- dermal exposure to PCBs in condensate and inhalation exposure either to PCBs in fugitive emissions of natural gas or to PCBs volatilized from condensate.

Because natural gas is flammable and toxic, the natural gas pipeline system is necessarily a closed system. The most likely routes of exposure are dermal and inhalation exposure during cleanup of leaks and spills, maintenance and cleaning of equipment, and removal of PCB-contaminated condensate. This exposure assessment examines potential exposure to PCBs in condensate at concentrations of 50 mg/kg, 25 mg/kg, and 2 mg/kg. Estimated exposure levels are summarized in Table Z-2.

Z.3.1. Dermal Exposure

Maximum hypothetical dermal exposure to PCBs in condensate was estimated using the following assumptions:

- All condensate contains PCBs at concentrations of 50, 25, or 2 mg/kg.
- Frequency of exposure is 240 days/year or 12 days/yr.
- Exposure continues for 38.5 years.
- 100 percent of the PCBs contacting the skin are absorbed.
- 870 cm² of skin (surface area of both hands) are coated with a film of condensate with a thickness of 0.0016 cm (Versar 1983).
- The density of the condensate is 1 g/cm³.

Except for the assumption on density of the condensate, these assumptions were used in the exposure assessment for hydraulic fluid in Volume IV of this document.

The following equation was used to estimate dermal exposure:

$$A = F \times S \times E \times R$$

where A = Annual PCB dermal exposure (mg/yr)

F = Frequency of exposure (times/yr)

S = Skin area exposed (cm²)

E = PCB exposure level (mg/cm²)

R = Fraction of available PCBs absorbed through the skin
(100 percent).

For liquids,

$$E = T \times L \times C$$

where T = Liquid film thickness on skin (cm)

L = Density of liquid (kg/cm³)

C = PCB concentration in the liquid (mg/kg).

Assuming that all condensate contains PCBs at a concentration of 50 mg/kg, maximum hypothetical dermal exposure to PCBs in condensate is estimated to be 16.7 mg/year, and the lifetime average daily dose* for a 70 kg man over a 38.5 year exposure period is 3.6×10^{-4} mg/kg/day. This is slightly lower than maximum hypothetical exposure to PCBs in hydraulic fluids because the density of natural gas condensate was assumed to be lower than the density of hydraulic fluid.

It is quite unlikely that any employee will be exposed to 16.7 mg/year of PCBs for several reasons. First, it appears from data submitted by gas transmission companies that draining of condensate does not occur daily, but rather approximately monthly. Often companies have found no condensate at collection points during some periods of the year. Second, PCB concentrations vary, and it is unlikely that condensate will uniformly contain concentrations of 50 mg/kg. Third, exposure to condensate containing 50 mg/kg PCBs for 38.5 years is unlikely. Because no existing PCB sources have been identified, PCB concentrations in condensate should decrease as PCBs are removed from the

*Calculated by:

mg/yr x 38.5 yrs (of exposure)/life ÷ 25,550 days/life ÷ 70 kg

pipelines. Fourth, many companies state that they require employees to wear protective clothing when handling condensate. Fifth, the draining procedure is at least partially enclosed. If condensate containing concentrations of PCBs of 50 mg/kg or less is excluded from the TSCA ban, however, companies may cease to require protective equipment and special handling of condensate.

The dermal exposure level estimated under an alternative scenario which assumes exposure to condensate 12 times a year is 0.8 mg/year, and the lifetime average daily dose for a 70 kg man over a 38.5 year period is 1.8×10^{-5} mg/kg/day.

2.3.2. Inhalation Exposure

Inhalation exposure to PCBs evaporating from condensate was estimated using the following assumptions:

- The maximum concentration of PCBs in air above condensate containing 50 mg/kg PCBs is 2.9×10^{-4} mg/m³ at 25°C. If the PCB concentration in the condensate is 25 mg/kg or 2 mg/kg, maximum airborne concentrations of PCBs are 1.4×10^{-4} mg/m³ or 1.1×10^{-5} mg/m³, respectively (see Attachment D).
- An individual is exposed 8 hours/day either 240 days/year or 12 days/year (see discussion of assumptions for estimating dermal exposure).
- The breathing rate is 1.2 m³/hour.
- Exposure continues for 38.5 years.
- 100 percent of the PCBs inhaled are absorbed.

Inhalation exposure is calculated with the following equation:

$$B = F \times I \times E \times D$$

where

B = annual PCB inhalation exposure (mg/yr)

F = Frequency of exposure (days/yr)

I = Inhalation rate (m³/hr)

E = PCB exposure level (mg/m³)

D = Duration of exposure (hrs/day).

Maximum hypothetical inhalation exposure to PCBs vaporizing from condensate containing concentrations of 50 mg/kg PCBs is 0.67 mg/year if exposure occurs daily and 0.033 mg/year if exposure occurs monthly. The associated lifetime (average daily dose* for a 70 kg man over a 38.5 yr exposure period is 1.4×10^{-5} . For the reasons stated in the section on dermal exposure, these estimated exposure levels are believed to be much higher than actual exposure levels.

It is assumed that fugitive emissions of natural gas are well controlled in order to prevent fires and explosions and that exposure to PCBs from this source is negligible.

Z.4. Consumer Exposure

When PCBs were discovered in natural gas pipelines, there was major concern that widespread exposure of natural gas customers might occur. In 1980, the natural gas industry had 43,300,000 residential customers. Average annual national consumption per customer was 111.4 MMBtu ($3,080 \text{ m}^3$). The states with the highest annual consumption per customer were Alaska, 216.9 MMBtu ($6,000 \text{ m}^3$), and Michigan, 172.8 MMBtu ($4,780 \text{ m}^3$) (AGA 1980).

Concentrations of PCBs found in natural gas, indoor air of residences using natural gas, and indoor air of control residences that do not use natural gas are summarized in Table Z-3. There is no evidence that natural gas contributes to the PCB level in residential indoor air.

A maximum hypothetical exposure to PCBs was calculated using the following assumptions:

- A residence uses $4,780 \text{ m}^3$ /year of natural gas.

*Calculated by:

$\text{mg/yr} \times 38.5 \text{ yrs (of exposure)/life} + 25,550 \text{ days/life} \div 70 \text{ kg}$

Table Z-3. PCBs in Natural Gas and Indoor Air

| Description | Reporting period | Samples analysed | No. of times PCBs detected | Concentrations (µg/m³) | | Comments |
|--------------------------------------|--------------------|------------------|----------------------------|------------------------|------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| | | | | Min. | Mean ^a Max. | |
| I. Natural gas in transmission lines | | | | | | |
| A. Company A | 6-2-82 to 12-15-82 | 9 | 0 | | | Detection limit = 0.2 µg/m³. Associated condensate found with 6 samples. PCB concentration ranged from 1 mg/kg to 3,577 mg/kg; mean = 1,247 mg/kg. |
| B. Company B | 1-82 to 4-83 | 9 | 0 | <0.1 | <3.7 | Detection limits were about 3.5 µg/m³ for 6 samples and 0.1 µg/m³ for 3 samples. No condensate was found at any of the sampling points. |
| C. Company C | 2-24-83 | 1 | 0 | | | Detection limit in gas = 10 µg/m³; 14.1 mg/kg of PCBs found in associated liquid condensate. |
| | 9-28-82, 9-29-82 | 2 | 0 | | | Detection limit in gas = 0.04 µg/m³. No condensate found. |
| | 2-22-83 to 2-23-83 | 2 | 0 | | | Detection limit = 10 µg/m³. PCB concentration in associated condensate <5 mg/kg. |
| | 2-26-82 to 9-29-82 | 7 | 2 | <0.04 | 0.53 0.70 | Detection limit = 0.04 µg/m³ or 0.1 µg/m³. PCB concentration in associated condensate <10 mg/kg. |
| D. Company D | 8-5-82 to 2-9-83 | 9 | 0 | | <17 | Insufficient volume of condensate found for analysis. |
| E. Company E | 2-11-82 to 2-1-83 | 11 | 0 | <0.08 | <0.143 | No condensate found. |

Table Z-3. (continued)

| Description | Reporting period | Samples analysed | No. of times PCBs detected | Concentrations ($\mu\text{g}/\text{m}^3$) | | Comments |
|--------------------------------------------------|---------------------|------------------|----------------------------|---------------------------------------------|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | | | | Min. | Mean ^a Max. | |
| I. Natural gas in transmission lines (continued) | | | | | | |
| F. Company F | 8-2-82 to 2-7-83 | 6 | 0 | | <17 | No condensate found or insufficient quantity for analysis. |
| G. Company G | 10-17-82 to 1-21-83 | 8 | 4 | <0.1 | 381 1,050 | Detection limit = 0.1 to 20 $\mu\text{g}/\text{m}^3$. Levels in the four samples where PCBs were detected were 1.4, 3.5, 470, and 1,050 $\mu\text{g}/\text{m}^3$. No condensate found. |
| H. Company H | 5-25-82 to 3-22-83 | 20 | 9 | <0.02 | 30 257 | Detection limit = 0.02 $\mu\text{g}/\text{m}^3$. Mean of samples where PCBs were detected is 1.1 $\mu\text{g}/\text{m}^3$ if the 257 $\mu\text{g}/\text{m}^3$ measurement is excluded. There was 1 oz. of condensate with a PCB concentration of 2,300 mg/kg found at the point where 257 $\mu\text{g}/\text{m}^3$ of PCBs was measured in the natural gas. No other condensate was found. |
| I. Company I | 9-21-81 to 3-22-83 | 24 | 7 | <2 | 42 260 | Detection limit = 2.0 $\mu\text{g}/\text{m}^3$. |
| J. Company J | No data reported | | | | | |
| K. Company K | 2-10-82 to 3-22-83 | 15 | 0 | | | Detection limit = 0.004 $\mu\text{g}/\text{m}^3$. No condensate found for 7 of the samples. 1 to 150 ml of condensate collected at remaining sample points with PCB concentrations from 61 mg/kg to 159 mg/kg. |
| L. Company L | 6-8-82 to 12-22-82 | 3 | 2 | <0.2 | 10 16.3 | Detection limit = 0.2 $\mu\text{g}/\text{m}^3$. |

Table Z-3. (continued)

| Description | Reporting period | Samples analysed | No. of times PCBs detected | Concentrations (µg/m ³) | | Comments |
|---------------------------------------------------------------------------------------------|--------------------|------------------|----------------------------|-------------------------------------|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | | | | Min. | Mean ^a Max. | |
| I. Natural gas in transmission lines (continued) | | | | | | |
| M. Company M | 2-22-82 to 2-28-83 | 12 | 0 | | | Detection limit = 0.002 µg/m ³ . No condensate found. |
| N. Totals | 9-81 to 4-83 | 138 | 24 | <0.004 | 71 1,050 | Mean, including samples where PCBs were not detected set equal to zero, = 15.3 ug/m ³ . If concentrations in samples where PCBs were not detected are set equal to one-half the detection limit, mean = 18.6 ug/m ³ |
| II. Natural gas in distribution lines | | | | | | |
| A. San Francisco area | | | | | | |
| | 4-81 to 6-81 | 21 | 0 | <0.2 | <1 | Data submitted to EPA Region IX by a distribution company. Detection limits = 0.2 µg/m ³ or 1 µg/m ³ . |
| B. New York State | | | | | | |
| 1. New York State monitoring survey - 12 participating distribution companies. ^c | 4-82 to 1-83 | | | | | Data submitted by several distribution companies in New York to the New York Department of Health. |
| • Natural gas at gate stations - New York State monitoring | | 205 | 66 | <0.02 | 0.71 ^b 51 | Detection limits = 0.02 µg/m ³ to 0.8 µg/m ³ . |
| • Natural gas at regulator stations in distribution systems | | 31 | 11 | <0.04 | 0.53 ^b 6.3 | Detection limits = 0.04 µg/m ³ to 0.2 µg/m ³ . Nine utilities obtained samples. |

Table Z-3. (continued)

| Description | Reporting period | Samples analysed | No. of times PCBs detected | Concentrations ($\mu\text{g}/\text{m}^3$) Min. ^a Mean ^a Max. | Comments |
|--------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|------------------|----------------------------|-----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> Natural gas in service lines to residences | | 51 | 18 | <0.05 0.44 ^b 4.30 | Detection limits = 0.05 $\mu\text{g}/\text{m}^3$ to 1 $\mu\text{g}/\text{m}^3$. |
| II. Natural gas in distribution lines (continued) | | | | | |
| 2. Survey of customers by a New York distribution company | | | | | |
| <ul style="list-style-type: none"> Natural gas in service lines to residences of customers where condensate was found in gas meters | | 63 | 26 | <0.1 8 23 | Detection limits = 0.1 to 13 $\mu\text{g}/\text{m}^3$. Mean detection limit = 1.4 $\mu\text{g}/\text{m}^3$. |
| <ul style="list-style-type: none"> Natural gas in service lines to residences of customers where condensate was not found in gas meters | | 178 | 103 | <0.06 6.4 41 | Detection limits = 0.03 to 9 $\mu\text{g}/\text{m}^3$. |
| III. Indoor air | | | | | |
| A. San Francisco area owners of gas ranges | 9-4-81 to 9-7-81 | | | | Data submitted to EPA's Region IX by a distribution company. |
| 1. Background kitchen air | | 12 | 9 | <0.01 0.02 0.04 | Detection limits = 0.01 $\mu\text{g}/\text{m}^3$. |
| 2. Air with range operating | | 12 | 8 | <0.01 0.035 0.07 | Detection limits = 0.01 $\mu\text{g}/\text{m}^3$ except for one sample where detection limit = 1 $\mu\text{g}/\text{m}^3$ because of interfering compounds. |

Table Z-3. (continued)

| Description | Reporting period | Samples analysed | No. of times PCBs detected | Concentrations (µg/m ³) Min. Mean ^a Max. | Comments |
|---------------------------------------------------------------------------------------------|------------------|------------------|----------------------------|--------------------------------------------------------------------|----------------------------------------------------|
| III. Indoor air (continued) | | | | | |
| B. New York State | 4-82 to 1-83 | | | | |
| 1. New York State monitoring survey - 12 participating distribution companies ^c | | | | | |
| • Kitchen air - customers with gas ranges | | 53 | 10 | <0.01 0.08 ^b 0.70 | Detection limits = 0.01 to 0.1 µg/m ³ . |
| - controls (no use of natural gas) | | 50 | 11 | <0.01 0.14 ^b 1.08 | Detection limits = 0.01 to 0.1 µg/m ³ . |
| • Air above operating range | | 53 | 9 | <0.01 0.07 ^b 0.25 | |
| 2. Survey of customers by a New York distribution company | | | | | |
| • Kitchen air - Residences of customers where condensate was found in gas meters | | 62 | 0 | <0.05 <5 | Detection limits = 0.05 to 5 µg/m ³ . |
| - Residences of customers where condensate was not found in gas meters | | 115 | 0 | <0.02 <0.8 | Detection limits = 0.02 to 0.8 µg/m ³ . |
| • Air above gas range - Residences of customers where condensate was found in gas meters | | 14 | 0 | <0.1 <0.5 | Detection limits = 0.1 to 0.5 µg/m ³ . |

Table Z-3. (continued)

| Description | Reporting period | Samples analysed | No. of times PCBs detected | Concentrations ($\mu\text{g}/\text{m}^3$) | | | Comments |
|-----------------------------------------------------------------------|------------------|------------------|----------------------------|---------------------------------------------|-------------------|------|----------|
| | | | | Min. | Mean ^a | Max. | |
| - Residences of customers where no condensate was found in gas meters | | 48 | 2 | 0.2 | 0.2 | 0.2 | |

^a Unless otherwise specified, the mean is the mean of all samples where PCBs were detected.

^b The mean represents the mean of all samples with concentrations set equal to one-half of the detection limit for those samples where no PCBs were detected.

^c Source: New York State Natural Gas Utilities (1982).

Source: Information submitted voluntarily to EPA by natural gas transmission and distribution companies, unless otherwise noted.

- All of the gas contains PCBs at concentrations of 41 ug/m³ (the highest concentration measured in natural gas service lines to residences) or 8 ug/m³ (the highest mean PCB concentration in gas in service lines found in 3 studies). (See Table Z-3, II.)
- None of the PCBs are directly vented to outdoor air; all of the PCBs are released into an indoor air volume of 230 m³. This is the weighted average of the estimated volumes of 4- and 6- room dwellings (JRB 1982).
- The air exchange rate is assumed to be 0.87 changes/hr. This is the weighted average of the air exchange rates for 4- and 6- room dwellings (JRB 1982).
- An individual spends 73 percent of his or her time at home (Versar 1982).
- Average inhalation rate is 0.79 m³/hr (Versar 1982).

The quantity of PCBs entering the home is:

$$4,780 \text{ m}^3 \text{ of natural gas} \times 41 \text{ ug/m}^3 = 195,980 \text{ ug/yr.}$$

If the PCBs are assumed to be released at a steady rate throughout the year, they will be diluted by a volume of air estimated as follows:

$$230 \text{ m}^3 \times 0.87 \text{ exchanges/hr} \times 24 \text{ hrs/day} \times 365 \text{ days/year} = 1.75 \times 10^6 \text{ m}^3/\text{yr}$$

The fact that the gas is consumed at different rates throughout the year will not affect the final exposure estimate.

Average concentration of PCBs in indoor air is estimated to be:

$$\frac{195,980 \text{ ug/yr}}{1.75 \times 10^6 \text{ m}^3/\text{yr}} = 0.1 \text{ ug/m}^3$$

Yearly inhalation exposure to this concentration is estimated as follows:

$$0.1 \text{ ug/m}^3 \times 0.79 \text{ m}^3/\text{hr} \times (24)(0.73) \text{ hr/day} \times 365 \text{ day/yr} = 500 \text{ ug/yr.}$$

Continued exposure at this level for 70 years results in an average lifetime daily dose of 2×10^{-5} mg/kg/day for a 70-kg individual.

If the PCB concentration in the natural gas is assumed to be 8 ug/m^3 , estimated yearly exposure is 0.1 mg/yr and lifetime average daily dose is 3.8×10^{-6} mg/kg/day.

These maximum hypothetical exposures are likely to be much higher than actual exposure for several reasons:

- PCBs in gas pipelines move around, and concentrations in natural gas change with time. Thus it is unlikely that any individual could be exposed to these high concentrations for a 70-year lifetime.
- Transmission and distribution companies are removing PCBs from their pipelines. The concentration of 8 ug/m^3 used in this assessment came from a study of air inside residences where PCB-laden condensate was found in gas meters. This condensate contained PCBs at very high levels (1,000 to 10,000 mg/kg) (see Table Z.1-IIC). If PCBs in condensate are reduced to less than 50 mg/kg, concentrations in the natural gas and consumer exposure should be greatly reduced.
- There is no evidence that PCBs at the levels estimated are escaping into residences. The PCB indoor air levels in homes that use natural gas supplied by pipelines containing PCBs are about the same as levels in homes that do not use natural gas (see Table Z-3, III).

A final issue is whether PCBs passing through the flame of a gas-range or furnace will form polychlorinated dibenzofurans (PCDFs). PCDFs are toxic chemicals that have been found in the soot formed during combustion of PCB transformer fluid (Versar 1984). A study of the pyrolysis in the presence of air of 2,4,5,2',4',5'-hexachlorobiphenyl, 2,4,6,2',4',6'-hexachlorobiphenyl, and Aroclor 1254 showed the optimum temperature for formation of PCDFs to be below 700°C. At 700°C and above, complete decomposition (greater than 99.9 percent) of the PCB molecule occurred (Buser et al. 1978). The temperature of the flame produced by combustion of natural gas is 1,700°C to 1,900°C (Knisely 1969). There should be no PCDF formation under these conditions.

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ATTACHMENT AA

Hypothetical Consumer Exposure to PCBs Potentially Released to Air from Moth Control Agents and Space Deodorants

A.A.1. Introduction

The purpose of this attachment is to estimate maximum probable consumer exposure to PCBs from consumer products containing chlorinated benzenes used for moth control and space deodorants. This exposure scenario was selected based on the following information: 1) PCBs have been detected in chlorinated benzenes; 2) chlorinated benzenes have a very high potential for PCB contamination⁺; and 3) dichlorobenzenes are widely used in consumer products for the purposes of moth control and air deodorizing.

A.A.2. Estimation of Indoor PCB Air Concentration

Separate estimates of indoor PCB air concentrations were made for mothproofing products and space deodorants to reflect expected differences in exposure resulting from characteristic use patterns. The following assumptions were made in order to estimate potential indoor air levels:

Space Deodorants

- Deodorants are used in a poorly ventilated bedroom with an air volume of 27 m³ (i.e., 11 ft. x 11 ft. x 8 ft.). Because bedroom door may be closed, an air exchange rate of 0.5 air changes per hour (ACH) is assumed.
- 50 g of space deodorant are used at a time. Deodorant is replaced monthly. (Space deodorants are commonly sold in 50 g units).*

Moth Control Products

- Products are used in a home with an air volume of 230 m³ and an air exchange rate of 0.87 ACH. These parameters represent the weighted average of estimates for 4- and 6- room dwellings (JRB 1982).
- 450 g of product is used annually. This amount represents a common unit by which the product is available to consumers.

⁺Based on analysis of incidental PCB generation contained in memorandum from Stanley J. Cristol to Robert Westin dated February 10, 1983.

*This scenario represents a common use pattern for space deodorants when they are used to deodorize diaper hampers in bedrooms occupied by babies.

- As a worst case, all PCBs are released via sublimation within one month of the installation of fresh deodorant.
- As a worst case, all PCBs are released via sublimation within one year.

Based on the above-mentioned assumptions, the estimated time-weighted average (TWA) PCB air concentration can be calculated as follows:

$$\text{Space deodorants TWA} = \frac{(\text{PCB concentration in deodorant}) \times (\text{mass of deodorant in room})}{(\text{volume of room}) \times (\text{air exchange rate}) \times (730 \text{ hours/month})}$$

$$\text{Moth control TWA} = \frac{(\text{PCB concentration in deodorant}) \times (\text{mass of product in home})}{(\text{volume of home}) \times (\text{air exchange rate}) \times (8760 \text{ hours/year})}$$

The TWA concentrations calculated for three hypothetical PCB concentrations in dichlorobenzenes are given in Table AA-1 for space deodorants and moth control products.

Table AA-1. Estimated PCB Air Concentrations Resulting from the Use of Space Deodorants and Moth Control Products

| PCB concentration in product (mg/kg) | Estimated PCB TWA in room with deodorant (ug/m ³) | Estimated PCB TWA in house with moth control product, (ug/m ³) |
|--------------------------------------|---------------------------------------------------------------|----------------------------------------------------------------------------|
| 50 | 2.5×10^{-1} | 1.3×10^{-2} |
| 25 | 1.3×10^{-1} | 6.4×10^{-3} |
| 2 | 1.0×10^{-2} | 5.1×10^{-4} |

A.A.3. Estimation of Individual Annual Exposures

The estimation of individual annual exposures is presented in Table AA-1 for individuals sleeping in closed bedrooms containing space deodorants, and individuals living in homes where moth control products are used. The deodorant scenario is calculated both for an adult spending 33 percent of his/her time (8 hours of sleep) and for a one-year old baby spending 58 percent of his/her time (14 hours of sleep) in the room

containing the space deodorant. The resting inhalation rates for babies and adults are assumed to be $0.09 \text{ m}^3/\text{hr}$ and $0.45 \text{ m}^3/\text{hr}$, respectively (JRB 1983). The moth control product exposure scenario is calculated for an adult spending 73 percent of his/her time at home (Versar 1982) with an average inhalation rate of $0.79 \text{ m}^3/\text{hr}$.

Table AA-2. Estimated Annual Individual Inhalation Exposures to PCBs in Moth Control Products and Space Deodorants

| PCB concentration in product (mg/kg) | Annual individual PCB exposure (mg/yr) | | |
|--------------------------------------|----------------------------------------|-------|-------------------------------|
| | Space deodorant 1-year old | Adult | Moth control product Adult |
| 50 | 0.11 | 0.33 | 0.066 |
| 25 | 0.059 | 0.17 | 0.032 |
| 2 | 0.0046 | 0.013 | 0.0026 |

References

JRB. 1982. Projected exposure to low volume chemicals under proposed exemptions from premanufacture notice. Draft Final Report. Washington, D.C.: U.S. Environmental Protection Agency. Office of Toxic Substances. Contract No. 68-01-5793.

JRB. 1983. Generic premanufacture notification report on waxes. Draft Final Report. Washington, D.C.: U.S. Environmental Protection Agency. Office of Toxic Substances. Contract No. 68-01-5793.

Versar. 1982. Exposure assessment for polymer exemptions: consumer and environmental exposure to the monomers vinyl chloride, styrene, toluene diisocyanate, acrylamide, acrylic acid, and acrylonitrile. Final report. Washington, D.C.: U.S. Environmental Protection Agency, Office of Toxic Substances. Contract No. 68-01-6271.

ATTACHMENT BB

Hypothetical Dermal Exposures to PCBs in Cosmetics/ Personal Hygiene Products

B.B.1. Introduction

This attachment investigates the potential dermal exposures to incidental PCBs from consumer products used as cosmetics or for personal hygiene. Many cosmetics, deodorant soaps, bath preparations, shampoos, and skin lotions contain chemical constituents which may potentially contain PCBs formed as by-products during manufacture. Chemicals suspected of containing incidental PCBs include one or more that may serve each of the following functions in this class of consumer products: fragrance, emollient, surfactant, and preservative.

The widespread consumer use of cosmetics and personal hygiene products suggests that a large population may be exposed to PCBs from dermal contact with these products if the suspect chemicals do contain incidental PCBs. The analysis presented in this attachment is restricted to consideration of dermal exposure. Inhalation exposure is expected to be insignificant compared to dermal exposure because the products of interest are used in small quantities and at ambient temperature, conditions allowing for negligible volatilization of PCBs to air.

B.B.2. Selection of Maximum Probable Individual Exposure Scenarios

The family of consumer products in the cosmetic/personal hygiene category is so large and diverse that virtually countless possible scenarios might be investigated. We selected two product/use categories that are expected to offer the highest potential for exposure, based on frequency of use and quantity of product applied to skin. Consumer use of deodorant soaps was selected because soaps are used daily over large skin areas. Exposure via skin lotions was investigated because significant quantities of lotion may remain in contact with the skin for extended periods of time, and lotions may be used daily over large skin

areas. Exposures were calculated separately for each product constituent potentially containing PCBs (i.e., fragrance, emollient, etc.) using appropriate formulation factors. It should be stressed that it is highly unlikely that any one product would contain all PCB-contaminated constituents.

B.B.3 Estimation of Annual Individual Exposures (Method 1)

The following assumptions were made in estimating annual individual dermal exposures to soaps and skin lotions (an alternative method of estimating exposure via soaps is presented in Section B.B.4):

Deodorant Soaps

- Soap is used daily. One bar (128 g) of soap is used per month per individual, or 0.0043 kg/event or day. All PCBs in the soap are available for dermal absorption.
- Deodorant soap contains 50 percent by weight surfactant, 5 percent by weight preservative, and 5 percent by weight fragrance. These values represent maximum figures likely, based on Gosselin et al. (1976).
- One or more of the above constituents is contaminated with PCBs.
- The effect of duration is not taken into account when 100 percent absorption is assumed. Thus, soaps are treated no differently from skin lotions in the exposure estimates, even though soaps are generally washed off within a few minutes of application.

Skin Lotions

- Skin lotion is used at a rate of 7 g/day (0.007 kg/event) for 365 days per year. This estimate is based on informal testing of lotion use by Versar personnel. All PCBs in the lotion are available for dermal absorption.
- The lotion contains 5 percent by weight humectant, 10 percent by weight surfactant, 5 percent by weight preservative, and 5 percent by weight fragrance. These values represent the maximum figures expected based on information in Gosselin et al. (1976).
- One or more of the above constituents is contaminated with PCBs.

Using the above listed assumptions, the annual exposure or absorbed dose was calculated with the following general equation:

$$\begin{array}{rclclcl} \text{Amount PCBs} & & \text{PCBs available} & & \text{Frequency of} & & \text{Absorption} & & \\ \text{absorbed} & = & \text{for absorption} & \times & \text{exposure} & \times & (\%) & & \text{(BB-1)} \\ \text{(mg/yr)} & & \text{(mg/event)} & & \text{(events/yr)} & & & & \end{array}$$

where

$$\text{PCBs available for absorption (mg/event)} = A \times B \times C$$

$$A = [\text{PCB}] \text{ in constituent (mg/kg)}$$

$$B = \text{Quantity of product used (kg/event)}$$

$$C = \text{Weight fraction of constituent in product}$$

$$\text{Frequency} = 365 \text{ events per year}$$

$$\text{Absorption} = 100 \text{ percent}$$

Based on the assumptions and calculations discussed above, the maximum probable consumer exposures to PCBs via dermal contact with deodorant soaps and skin lotions are presented in Table BB-1.

B.B.4 Estimation of Annual Individual Exposures to PCBs via Soap (Alternate Method)

It is obvious that all of the PCBs in a bar of soap will not be dermally absorbed. This scenario provides an alternate approach to estimating dermal exposure to PCBs in soap. It departs from the other exposure scenarios by assuming the PCBs may be removed from the skin by wiping. PCBs are no longer assumed to be absorbed immediately upon contact with the skin.

The following assumptions were used to estimated annual dermal exposure:

- One bar (128 g) of soap is used per month per individual, or 0.0043 kg/day.
- The soap contains 50 percent by weight surfactant, 5 percent by weight preservative, and 5 percent by weight fragrance. These values represent maximum figures likely, based on Gosselin et al. (1976).

Table BB-1. Estimated Annual Individual Exposures to PCBs in Soaps and Skin Lotions

| PCB concentration in constituent (mg/kg) | Estimated annual individual exposure (mg/yr) | | | | |
|------------------------------------------------|----------------------------------------------|-------------------|---------------------|------------------|--------------|
| | <u>Humectant</u> | <u>Surfactant</u> | <u>Preservative</u> | <u>Fragrance</u> | <u>Total</u> |
| <u>Soaps (Method 1)^a</u> | | | | | |
| 50 | - | 38 | 3.8 | 3.8 | 46 |
| 25 | - | 19 | 1.9 | 1.9 | 23 |
| 2 | - | 1.5 | 0.15 | 0.15 | 1.8 |
| <u>Skin lotions^a</u> | | | | | |
| 50 | 6.4 | 13 | 6.4 | 6.4 | 32 |
| 25 | 3.2 | 6.4 | 3.2 | 3.2 | 16 |
| 2 | 0.26 | 0.51 | 0.26 | 0.26 | 1.3 |
| <u>Soaps (Alternate Method)^b</u> | | | | | |
| 50 | - | 0.042 | 0.0042 | 0.0042 | 0.050 |
| 25 | - | 0.021 | 0.0021 | 0.0021 | 0.025 |
| 2 | - | 0.0017 | 0.00017 | 0.00017 | 0.0020 |

^aSee Section B.B.3 for details and assumptions.

^bSee Section B.B.4 for details and assumptions.

- One or more of the above constituents is contaminated with PCBs.
- An individual bathes daily in 10 gallons of water.
- 2.26 mg/cm²* of soap film (Versar 1983) are deposited over the surface area of the body (18,000 cm).

The concentration of soap in the film, therefore, is 114 mg/kg (0.0043 kg/10 gal). Using the above listed assumptions, the annual exposure or absorbed dose was calculated using Equation BB-1. The frequency is assumed to be 365 days per year and the absorption rate is assumed to be 100 percent. In this case, however,

PCBs available for absorption = A x B x C x D x E.

where

A = amount of film deposited on skin (2.26 mg/cm²)

B = surface area of skin exposed (18,000 cm²)

C = concentration of soap in film (114 x 10⁻⁶ mg soap/mg film)

D = concentration of constituent in soap (mg/mg)

E = concentration of PCBs in constituent (mg/mg)

Based on the assumptions and the calculations discussed above, the consumer exposure to PCBs via dermal contact with soaps and deodorant bars are presented in Table BB-1.

*This is the measured amount of a 50% bath, 50% water mixture retained on the skin after immersion of hands into the solution followed by a partial wipe with a rag.

References

Gosselin RE, Hodge HC, Smith RP, Gleason MN. 1976. Clinical toxicology of commercial products, 4th ed. Baltimore, MD: Williams & Wilkins Co.

ATTACHMENT CC

Hypothetical Consumer Exposure to PCBs in Printed Matter

C.C.1. Introduction

This attachment investigates hypothetical individual dermal exposures to PCBs in magazines and newspapers. Consumers may be exposed to PCBs as a result of contact with various printed materials, including newspapers, magazines, board and film packaging, and commercial brochures. Diarylide and phthalocyanine pigments, which contain PCB impurities at concentrations reportedly reaching 150 ppm (DCMA 1982) are used extensively in printing ink. The National Association of Printing Ink Manufacturers (NAPIM 1981) estimates that nearly 13 percent and 7 percent of the dollar value of printing ink produced by merchant companies in the U.S. in 1980 contained diarylide and phthalocyanine pigments, respectively. Phthalocyanine pigments account for an estimated 85 percent of all blue pigments used in color process printing (the method by which color photographs are reproduced in printed form) (NAPIM 1981). Moreover, based on data provided in NAPIM (1981), it appears that diarylides account for almost one third of the yellow pigments currently used in printing ink.

C.C.2. General Approach to Exposure Estimation

Under the assumption that newspaper and magazine reading constitute the greatest potential for consumer exposure to PCBs in printed matter, this attachment estimates maximum probable exposures based on assumed typical newspaper and magazine reading habits. The major assumptions concerning pigment content of printing inks and ink content of printed matter are based on data provided by NAPIM (1981). Assumptions concerning dermal contact with printed matter are based on Versar estimates. Maximum probable individual dermal exposures are estimated for four hypothetical PCB concentrations in pigments 2 ppm, 25 ppm, 50 ppm, and 150 ppm, due to the range reported by DCMA (1982).

C.C.3 Estimation of Annual Dermal Exposures

The following assumptions were used in estimating individual annual dermal exposures to PCBs from contact with newspaper and magazines:

- The pigment content in full-strength colored printing ink is approximately 30 percent by weight in newspaper ink and 22 percent by weight in magazine ink (NAPIM 1981).
- 100 kg of newspaper are printed per kg of colored ink. This value assumes 20 percent coverage of total page surface area. (NAPIM 1981).
- 43 kg of magazine paper are printed per kg of colored ink, assuming 50 percent coverage of total page surface area. (NAPIM 1981).
- 75 percent of magazine ink contains PCBs and 30 percent of newspaper ink contains PCBs. This estimate is based on the fact that not all ink used in printing will contain the pigments of concern, and black ink does not contain diarylide or phthalocyanine pigments.
- A typical newspaper weighs 0.45 kg and a typical magazine weighs 0.15 kg (Versar estimate).
- A person touches at most approximately 10 percent of the surface area of printed paper while reading a newspaper or magazine. Of the printed ink touched, 10 percent is deposited on the skin and is available for dermal absorption (Versar's estimate of an upper limit of the fraction of ink that could be removed during normal use). Therefore 0.1×0.1 or 0.01 of the printed ink is available for dermal absorption.

Using the above mentioned assumptions, dermal exposure to PCBs was calculated with the following equation:

$$\begin{array}{lclcl} \text{Amount PCBs} & = & \text{PCBs available} & \times & \text{frequency} & \times & \text{absorption} & & \text{(C-1)} \\ \text{absorbed} & & \text{for absorption} & & \text{of exposure} & & \text{(\%)} & & \\ \text{(mg/yr)} & & \text{(mg/event)} & & \text{(events/yr)} & & & & \end{array}$$

where

PCBs available for absorption (mg/event) = A x B x C x D x E x F

A = [PCB] in pigment (mg/kg)

B = weight fraction of pigment in printing ink (kg/kg)

C = weight fraction of colored inks in printed paper (kg/kg)

D = fraction of ink with PCBs

E = weight of printed article (kg/event)

F = fraction of printed ink available for absorption

Frequency = 7 newspapers/week x 52 weeks/yr = 364 events/yr

or,

3 magazines/week x 52 weeks/yr = 156 events/yr

Absorption = 100 percent.

Estimated individual annual exposures are presented in Table CC-1 based on the assumptions and calculations discussed in the preceding section.

Table CC-1. Estimated Individual Annual Dermal Exposures
to PCBs Associated with Newspaper and Magazine Readings

| <u>PCB concentration in pigment (mg/kg)</u> | <u>Absorbed dose (mg PCBs per year)</u> | | |
|-------------------------------------------------|-----------------------------------------|----------------------|----------------------|
| | <u>Newspaper</u> | <u>Magazines</u> | <u>Total</u> |
| 150 | 2.2×10^{-1} | 1.3×10^{-1} | 3.5×10^{-1} |
| 50 | 7.4×10^{-2} | 4.5×10^{-2} | 1.2×10^{-1} |
| 25 | 3.7×10^{-2} | 2.2×10^{-2} | 5.9×10^{-2} |
| 2 | 2.9×10^{-3} | 1.8×10^{-3} | 4.7×10^{-3} |

References

DCMA. 1982. Dry Color Manufacturers' Association. Comments in response to proposed rule on manufacture, processing, distribution and use of PCBs in closed and controlled waste manufacturing processes. July 8, 1982.

NAPIM. 1981. National Association of Printing Ink Manufacturers. Letter from James E. Renson (NAPIM) to the Dry Color Manufacturers' Association (DCMA) (dated March 27, 1981). In: Comments of DCMA in response to the proposed rule on manufacture, processing, distribution, and use of PCBs in closed and controlled waste manufacturing processes. (Dated July 8, 1982).

ATTACHMENT DD

Hypothetical Consumer Exposures to PCBs Potentially Occurring in Non-aerosol Consumer Paints

D.D.1. Introduction

The purpose of this attachment is to estimate maximum probable inhalation and dermal exposures to PCBs for consumers who use non-aerosol paints containing residual PCBs in their homes.* Two components of consumer paints may contain PCBs formed as by-products during the manufacture of the primary organic chemical: pigments and synthetic resins. Phthalocyanine and diarylide pigments, which contain incidental PCBs in concentrations ranging from 1 mg/kg to 150 mg/kg (DCMA 1982), are used as tinting components of the pigment system in some consumer paints (NPCA 1978, 1981). Diarylide pigments are used in some consumer paints, although they are used more often in industrial coatings. These pigments are normally used to enhance other pigments and are rarely, if ever, used alone in paints (MRI 1980). Phthalocyanine blue and green pigments, however, are among the most widely used organic pigments in paints (MRI 1980). Some chemical intermediates used in the manufacture of paint resins may also contain incidental PCBs. PCB concentrations in paint resins are expected to be considerably lower than PCB concentrations in intermediates, however, because the weight fraction of the PCB-contaminated chemical intermediate in resin manufacture is not expected to exceed one-fifth of the total paint resin (Versar estimate).

D.D.2. General Approach to Exposure Estimation

Of all the opportunities for consumer exposure to PCBs in paints, the maximum individual exposures are expected to result from three scenarios:

*See Attachment EE for estimation of exposures to PCBs from aerosol consumer paints.

- Inhalation of PCBs while painting the interior of a house.
- Dermal exposure from spilled paint while painting the interior of a house.
- Inhalation of PCBs while living in a house with a relatively new interior paint job.

The exposures associated with these scenarios are investigated in this attachment. While each scenario uses different assumptions regarding the duration, frequency, and extent of exposure, all scenarios assume that the same paint formulation will be used, that the interior of a house will be painted every five years, and that 100 percent of the PCBs will be absorbed. Exposures are estimated for three hypothetical PCB concentrations in paint pigments and resins: 2 mg/kg, 25 mg/kg, and 50 mg/kg. A fourth hypothetical PCB concentration, 150 mg/kg is used in calculations for exposures to paints containing PCB-contaminated pigments because the PCB concentration may reach 150 mg/kg in some pigments.

D.D.3. Estimation of Annual Individual Inhalation Exposures from Painting

This scenario investigates maximum probable inhalation exposures to PCBs resulting from painting the interior of a home. Though this exposure will only occur once in every five years, individual annual exposure is calculated based on the one year exposure occurs; the maximum probable exposure figures are not divided by a factor of five. The following assumptions were used regarding the PCB content of the paint.

- Interior wall paint contains 1.5 percent by weight of PCB-containing pigments. This is the maximum phthalocyanine pigment content expected by DCMA (1981).
- The PCB concentration in the paint pigment is 2, 25, 50, or 150 mg/kg.

- Interior paint contains 35 percent by weight of a resin (estimate based on informal survey of retail consumer paints, and on Gosselin et al. 1976). Twenty percent by weight of the chemical intermediates used in resin manufacture are contaminated with PCBs at 2, 25, or 50 ppm (Versar estimate). Therefore, the contaminated resin constituent represents 7 percent by weight of the total paint formulation. This estimate is truly worst case because most retail interior wall paints are of the latex type, which is not expected to contain PCB-contaminated resins.

In order to estimate inhalation exposure from painting, the PCB concentration in indoor air must first be estimated. A worst case estimate of the PCB air concentration resulting from evaporation of PCBs from paints can be made using Raoult's Law to estimate the vapor pressure of PCBs above the painted surface and then using Dalton's Law of Partial Pressures to estimate corresponding maximum air concentrations in the vicinity of the painted surface. The assumptions and equations pertaining to this approach are discussed in Attachment D and will not be repeated here. Other assumptions used in estimating annual individual inhalation exposures from painting include:

- Sixteen 4-hour painting sessions are required to paint a house.
- The inhalation rate during painting activities is 1.2 m³/hr.

The sequence of calculations required to estimate individual annual inhalation exposures from painting is presented below.

1. Calculation of PCB concentration in paint, contaminated pigment, and/or contaminated resin.

$$\begin{array}{lcl} \text{[PCB] in paint} & = & \text{PCB in contaminated} \times \text{weight fraction of} \\ \text{(mg/kg)} & & \text{constituent (mg/kg)} \quad \text{constituent in paint} \end{array}$$

2. Calculation of vapor pressure of PCBs above painted surface at 25°C using Raoult's Law (see Attachment D) and the PCB concentration in paint.

3. Calculation of maximum air level of PCBs (mg PCBs/m^3) using the vapor pressures calculated in Step 2 as input to Dalton's Law of Partial Pressures (see Attachment D), assuming an air temperature of 25°C .

4. Calculation of individual annual inhalation exposures, as

$$\begin{array}{lcl} \text{Individual annual} & [\text{PCB}] \text{ in} & \text{inhalation} \\ \text{exposure} & = \text{air} & \times \text{rate} \times \text{frequency} \times \text{duration.} \\ (\text{mg PCBs/yr}) & (\text{mg/m}^3) & (\text{m}^3/\text{hr}) \quad (\text{sessions/yr}) \quad (\text{hr/sessions}) \end{array}$$

The estimated PCB concentrations in paints, vapor pressures of PCBs, and maximum air concentrations of PCBs associated with each PCB level in pigments and resins examined are presented in Table DD-1. Corresponding estimated individual annual inhalation exposures are given in Table DD-2.

Table DD-1. Hypothetical PCB Vapor Pressures and Maximum Air Concentrations above a Painted Surface

| PCB concentration in paint constituent (mg/kg) | PCB concentration in paint (mg/kg) | PCB equilibrium vapor pressure (torr) at 25°C | Maximum PCB air concentration (mg/m^3) at 25°C |
|------------------------------------------------|------------------------------------|-------------------------------------------------------------|-------------------------------------------------------------------------|
| <u>Pigment</u> | | | |
| 150 | 2.3 | 9.2×10^{-10} | 1.3×10^{-5} |
| 50 | 0.75 | 3.0×10^{-10} | 4.3×10^{-6} |
| 25 | 0.38 | 1.5×10^{-10} | 2.2×10^{-6} |
| 2 | 0.030 | 1.2×10^{-11} | 1.7×10^{-7} |
| <u>Resin</u> | | | |
| 50 | 3.5 | 1.4×10^{-9} | 2.0×10^{-5} |
| 25 | 1.8 | 7.2×10^{-10} | 1.0×10^{-5} |
| 2 | 0.14 | 5.6×10^{-11} | 8.0×10^{-7} |

Table DD-2. Estimated Annual Individual Inhalation Exposures to PCBs Resulting from Painting the Interior of a House

| PCB concentration in paint constituent (mg/kg) | Annual individual inhalation exposure (mg/yr) | | |
|------------------------------------------------|-----------------------------------------------|----------------------|----------------------|
| | Pigment | Resin | Total |
| 150 | 1.0×10^{-3} | NA | NA |
| 50 | 3.3×10^{-4} | 1.5×10^{-3} | 1.8×10^{-3} |
| 25 | 1.7×10^{-4} | 7.7×10^{-4} | 9.4×10^{-4} |
| 2 | 1.3×10^{-5} | 6.1×10^{-5} | 7.4×10^{-5} |

D.D.4. Estimation of Annual Individual Dermal Exposures from Painting

This scenario investigates maximum probable dermal exposure to PCBs in consumer paints resulting from painting the interior of a home. The assumptions regarding frequency of exposure and the PCB content of consumer paints are identical to those used in the estimation of inhalation exposure while painting. In addition, the following assumptions were made regarding the quantity of paint spilled on the skin:

- Interior paint is assumed to have an average density of 5.7 kg/gallon (1.5 g/cm^3)(JRB 1982).
- During each of the sixteen painting sessions required to paint the interior of a house, a 0.0018-cm* thick paint film covering the equivalent of the total skin surface of one hand (435 cm^2) is spilled on the skin.

The equations used to calculate individual annual dermal exposures are given below:

$$\begin{array}{lclcl} \text{Amount PCBs} & & \text{PCB available} & \text{frequency of} & \text{absorption} & \text{(DD-1)} \\ \text{absorbed} & = & \text{for absorption} & \times & \times & \\ \text{(mg/yr)} & & \text{(mg/event)} & & \text{exposure} & \text{(\%)} \\ & & & & \text{(events/yr)} & \end{array}$$

*This is the average of the measured film thicknesses of five solutions on the skin after immersion of hands into the solution followed by a partial wipe with a rag: mineral oil, cooking oil, bath oil, 50% bath oil/50% water, and water (Versar 1983).

where,

PCBs available for absorption (mg/event) = A x B x C x D x E x F

A = [PCB] in paint constituent (mg/kg)

B = weight fraction of contaminated constituent in paint

C = skin surface area covered (cm²/event)

D = paint film thickness (cm)

E = paint density (g/cm³)

F = conversion factor; 10⁻³kg/g

Absorption = 100 percent.

The estimated individual annual dermal exposures are presented in Table DD-3 for each PCB concentration considered for paints with PCB-contaminated pigments, paints with PCB-contaminated resins, and paints with PCB-contaminated pigments and resins.

Table DD-3. Estimated Annual Individual Dermal Exposures to PCBs Resulting from Painting the Interior of a House

| PCB concentration in paint constituent (mg/kg) | Annual individual dermal exposure (mg/yr) | | |
|------------------------------------------------|-------------------------------------------|----------------------|----------------------|
| | Pigment | Resin | Total |
| 150 | 4.2x10 ⁻² | NA | 4.2x10 ⁻² |
| 50 | 1.4x10 ⁻² | 6.6x10 ⁻² | 8.0x10 ⁻² |
| 25 | 7.0x10 ⁻³ | 3.3x10 ⁻² | 4.0x10 ⁻² |
| 2 | 5.6x10 ⁻⁴ | 2.6x10 ⁻³ | 3.2x10 ⁻³ |

D.D.5. Estimation of Annual Individual Inhalation Exposures Resulting from Residing in a Home with a Painted Interior

The maximum probable individual inhalation exposures resulting from inhabiting a home with a relatively new interior paint job are estimated in this scenario. The assumptions regarding the paint density, PCB concentration in contaminated pigments and resins, and the weight fractions of pigments and resins in paints are identical to those used in the previous two scenarios in this attachment. In addition to those assumptions, the following assumptions were made regarding the quantity of PCBs in a painted house:

- The PCB-containing paint is used to paint 3,400 ft² of the house. This value is the weighted average paintable surface area for 4- and 6-room dwellings (JRB 1982).
- One gallon of paint can typically cover 400 ft² of surface area (JRB 1982). Therefore, approximately 8.5 gallons of paint will be required to cover 3,400 ft² of surface area.

Based on the above-mentioned assumptions, the mass of pigment and the mass of the PCB-contaminated portion of the resin were calculated using the following product:

$$\begin{array}{ccccccc} \text{Quantity of PCB-} & \text{weight fraction} & \text{paint} & \text{volume of} & & & \text{(DD-2)} \\ \text{contaminated paint} & \text{of constituent} & \text{x density} & \text{x paint} & & & \\ \text{constituent (kg)} & \text{in paint} & \text{(kg/gal)} & \text{(gal)} & & & \end{array}$$

The hypothetical wall paint used in this scenario would contain 0.73 kg of PCB-contaminated pigment and 3.4 kg of the PCB-contaminated component of the resin (which is one-fifth of the total mass of resin). Further assumptions needed to estimate indoor air concentrations include:

- All PCBs present in the paint will be released to indoor air within two years after paint application. The release rate using this assumption is higher than the evaporation rate used in Attachment S, which indicates that this is a worst case assumption. Diffusion of PCBs to the surface, rather than evaporation of PCBs from the painted surface, is likely to become the rate-limiting factor in controlling the release of PCBs to indoor air at some point in the period when evaporation takes place.
- The air volume in the house is assumed to be 230 m³. This is the weighted average of the estimated volumes of 4- and 6-room dwellings (JRB 1982).
- The air exchange rate in the house is assumed to be 0.87 changes/hr. This is the weighted average of the air exchange rates for 4- and 6-room dwellings (JRB 1982).

Based on the assumptions listed above, the estimated time-weighted (i.e., over two years) average (TWA) PCB air concentration can be calculated as follows for PCBs released from each paint constituent (i.e., pigment and resin):

$$\text{TWA} = \frac{(\text{PCB concentration in constituent}) \times (\text{mass of constituent applied})}{(\text{volume of home}) \times (\text{air exchange rate}) \times (8760 \text{ hrs/yr}) \times (2 \text{ yrs})}$$

The TWA concentrations calculated for the hypothetical PCB concentrations in the contaminated paint constituents are listed in Table DD-4.

Table DD-4. Estimated PCB Air Concentrations in a Home with a Painted Interior

| PCB concentration in paint constituent (mg/kg) | Estimated PCB TWA (mg/m ³) | | |
|------------------------------------------------|----------------------------------------|----------------------|----------------------|
| | Pigment | Resin | Total |
| 150 | 3.1x10 ⁻⁵ | NA | NA |
| 50 | 1.0x10 ⁻⁵ | 4.8x10 ⁻⁵ | 5.8x10 ⁻⁵ |
| 25 | 5.2x10 ⁻⁶ | 2.4x10 ⁻⁵ | 2.9x10 ⁻⁵ |
| 2 | 4.2x10 ⁻⁷ | 1.9x10 ⁻⁶ | 2.3x10 ⁻⁶ |

Annual PCB exposures for an individual spending 73 percent of his/her time at home (Versar 1982) with an average inhalation rate of $0.79 \text{ m}^3/\text{hr}$ are estimated in Table DD-5.

Table DD-5. Estimated Annual Individual Inhalation Exposures to PCBs Resulting from Inhabiting a Home with a Painted Interior

| PCB concentrations in paint constituent (mg/kg) | Annual individual PCB exposures (mg/yr) | | |
|-------------------------------------------------------|-----------------------------------------|----------------------|----------------------|
| | Pigment | Resin | Total |
| 150 | 1.6×10^{-1} | NA | NA |
| 50 | 5.1×10^{-2} | 2.4×10^{-1} | 2.9×10^{-1} |
| 25 | 2.6×10^{-2} | 1.2×10^{-1} | 1.5×10^{-1} |
| 2 | 2.1×10^{-3} | 1.0×10^{-2} | 1.2×10^{-2} |

References

DCMA. 1981. Dry Color Manufacturers' Association. Polychlorinated biphenyls unintentionally generated in the manufacture of diarylide and phthalocyanine pigments.

DCMA. 1982. Dry Color Manufacturers' Association. Comments to EPA re: proposed rule on manufacture, processing, distribution and use of PCBs in closed and controlled waste manufacturing processes. Submitted July 8, 1982.

Gosselin RE, Hodge HC, Smith RP, Gleason MN. 1976. Clinical toxicology of commercial products, 4th ed. Baltimore, MD: William J. Wilkins Co.

JRB. 1982. Projected exposure to low volume chemicals under proposed exemptions from premanufacture notice. Draft final report. Washington, DC: U.S. Environmental Protection Agency. Office of Toxic Substances. Contract No. 68-01-5793.

MRI. 1980. Midwest Research Institute. Chemical technology and economics in perspective - Task 5- a preliminary materials balance for dyes and pigments from benzidine and three benzidine derivatives. Revised draft final report. Washington, DC: U.S. Environmental Protection Agency. Office of Toxic Substances. Contract No. 68-01-3896.

NPCA. 1978. National Paint and Coatings Association. Written testimony to the EPA re: proposed rule on manufacturing processing, distribution in commerce, and use bans of polychlorinated biphenyls. Submitted August 30, 1978.

NPCA. 1981. National Paint and Coatings Association. Comments to EPA re: polychlorinated biphenyls manufacturing, processing, distribution in commerce and use prohibitions: PCBs in concentrations below fifty parts per million. Submitted November 16, 1981.

Versar. 1983. Exposure assessment for retention of chemical liquids on hands. Preliminary draft report. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances. Contract No. 68-01-6271.

ATTACHMENT EE

Hypothetical Dermal Exposure to PCBs from Consumer Textile Products

E.E.1. Introduction

This attachment estimates the maximum probable individual dermal exposures to PCBs from consumer textile products. PCBs are known to occur in phthalocyanine and diarylide pigments, which are used in textile printing. PCBs may also be produced incidentally in the manufacture of certain organic chemicals used in dyeing. Textiles that are used in consumer products which come in frequent contact with the skin are therefore a potential source of consumer exposure to PCBs. Inhalation exposure to PCBs in textiles is probably insignificant in comparison to dermal exposure because of the relatively small quantities of PCBs involved, coupled with the fact that evaporation of PCBs will be low at ambient temperatures. Of the textile products commonly used by consumers (including carpeting and upholstery), clothing and sheets involve the most dermal contact, hence represent the greatest potential for dermal exposure to PCBs. Apparel and sheets are therefore the consumer products investigated in this attachment.

E.E.2. General Approach to Exposure Estimation

Estimation of exposure to chemicals in clothing is difficult because, in addition to the dearth of data on dermal absorption, there is no accurate way to estimate the loss rate of dyes and pigments from fabrics (JRB 1983). In general, the bulk of color loss from fabrics is a result of washing, bleaching, exposure to light and heat, and other processes. Loss through dermal absorption is expected to be insignificant in comparison to loss through laundering; this assumption is reflected in the calculations presented in this attachment.

The exposure estimates for clothing and sheets assume as a worst case that an individual will be exposed to clothes and sheets containing PCBs on a daily basis. The exposure estimates are expected to represent the

maximum probable values for clothes and sheets in general, regardless of the source of PCBs and the method of incorporation into the fabric (i.e., textile printing on one side of fabric vs. textile dyeing). The assumptions concerning the rate of dye/pigment loss from fabrics and the relative quantities of dyes/pigments available for dermal absorption, while not based on chemical-specific data, are representative of values commonly used in exposure estimates.

Exposures were estimated for four hypothetical PCB concentrations in the pigment/dye 2 mg/kg, 25 mg/kg, 50 mg/kg, and 150 mg/kg, due to the range reported by DCMA (1982).

E.E.3 Estimation of Annual Dermal Exposures

The following assumptions were used in estimating dermal exposures to PCBs in textiles:

- Two kg of dark dyed or printed fabric is worn daily (365 days/year); clothing fabric has a maximum pigment/dye content of 5 percent by weight (estimate based on data presented in JRB 1983).
- The exposed individual sleeps nightly (365 days/yr) on two sheets that are dyed or printed extensively. Each sheet weighs 0.79 kg, 3 percent of which is pigment or dye (JRB 1983).
- Ten percent of the original pigment/dye is lost during a lifetime of 100 wearings/uses for both apparel and sheets. One percent of this loss is due to leaching while the apparel or sheet is being worn/used (as opposed to being lost during laundering). Therefore, 10^{-5} of the original pigment/dye (hence PCBs) is released for dermal absorption per wearing/use. (Assumptions based on JRB 1983.)

- When apparel or sheets are discarded, they are replaced with identical new products; therefore, an individual is exposed daily to dyes/pigments (hence PCBs) leached from the clothing and sheets throughout the year.

The annual exposure or absorbed dose is calculated as follows:

$$\begin{array}{rclcl} \text{Amount PCBs} & & \text{PCBs available} & \text{frequency of} & \text{absorption} & & \text{(EE-1)} \\ \text{absorbed} & = & \text{for absorption} & \times & \text{exposure} & \times & \text{(\%)} \\ \text{(mg/yr)} & & \text{(mg/event)} & & \text{(events/yr)} & & \end{array}$$

where

$$\text{PCBs available for absorption (mg/event)} = A \times B \times C \times D$$

A = [PCB] in pigment/dye (mg/kg)

B = weight fraction of pigment/dye in fabric

C = weight of fabric (kg/event)

D = fraction of pigment/dye released

Frequency = 365 days per year

Absorption = 100 percent.

Estimated individual annual dermal exposures to PCBs in clothing and sheets are presented in Table EE-1.

Table EE-1. Estimated Annual Individual Dermal Exposures
to PCBs in Clothing and Sheets

| PCB concentration in pigment/dye (mg/kg) | Individual annual dermal exposures (mg PCBs/yr) | | |
|------------------------------------------------|-------------------------------------------------|----------------------|----------------------|
| | Clothing | Sheets | Total |
| 150 | 5.5×10^{-2} | 2.6×10^{-2} | 8.1×10^{-2} |
| 50 | 1.8×10^{-2} | 8.7×10^{-3} | 2.7×10^{-2} |
| 25 | 9.1×10^{-3} | 4.3×10^{-3} | 1.3×10^{-2} |
| 2 | 7.3×10^{-4} | 3.5×10^{-4} | 1.1×10^{-3} |

References

DCMA. 1982. Dry Color Manufacturers' Association. Comments in response to proposed rule on manufacture, processing, distribution and use of PCBs in closed and controlled waste manufacturing processes. July 8, 1982.

JRB. 1983. Generic premanufacturing notification report on dyes. Draft final report. Washington, DC: U.S. Environmental Protection Agency. Office of Toxic Substances. Contract No. 68-01-5793.

ATTACHMENT FF

Hypothetical Dermal Exposures to PCBs in Consumer Cleaning Products

F.F.1. Introduction

This attachment estimates maximum probable individual exposures to incidentally produced PCBs that may be present in several common classes of consumer cleaning products. Chemicals that may contain PCBs as impurities are used in a variety of cleaning product formulations, including spot removers, general household cleaning products, and sanding aids/paint removers. This attachment estimates dermal exposures to PCBs resulting from the routine use of the three product classes mentioned above. Inhalation exposures are not estimated but are expected to be insignificant because of the low evaporation rate of PCBs at ambient temperatures and the relatively small quantities of product involved. One hundred percent dermal absorption is assumed in all calculations. Exposures are estimated for three hypothetical PCB concentrations in the PCB-contaminated constituent of each product: 2 mg/kg, 25 mg/kg, and 50 mg/kg.

F.F.2. Dermal Exposures to PCBs in Liquid Spot Removers

Chlorinated solvents are a major ingredient in liquid spot removers where concentrations may range as high as 100 percent of the product. Spot removers may be applied to textiles with a saturated cloth or a built-in applicator. Exposure estimates presented below assume that a saturated cloth will be used, as this will result in the greatest dermal contact with the cleaner. The following assumptions were used in estimating maximum probable individual exposure:

- Density of spot remover is 1.35 g/ml (Versar 1983a).
- In the process of using a saturated cloth to apply spot remover, one quarter of the skin surface area of one hand (110 cm²) is coated with a 0.0024 cm* thick solvent film, or 0.26 ml of solvent.

*This is the measured film thickness for a solution of 50% water/50% bath oil retained on the skin after immersion of hands into the solution followed by a partial wipe with a rag (Versar 1983b).

The following equation was used to calculate annual dermal exposures based on the assumptions listed above:

$$\begin{array}{ccccccc} \text{Amount PCBs} & & \text{PCBs available} & & \text{frequency} & & \text{absorption} & & \text{(FF-1)} \\ \text{absorbed} & = & \text{for absorption} & \times & \text{of exposure} & \times & \text{(\%)} & & \\ \text{(mg/yr)} & & \text{(mg/event)} & & \text{(events/yr)} & & & & \end{array}$$

where

$$\text{PCBs available for absorption (mg/event)} = A \times B \times C \times D$$

A = [PCB] in spot remover (mg/kg)

B = Quantity of spot remover on skin (ml/event)

C = Density of spot remover (g/ml)

D = Conversion factor; 10^{-3} kg/g

Frequency = One use per month for an annual frequency of 12 events per year (Versar 1983a)

Absorption rate = 100 percent.

Annual individual dermal exposures estimated using this approach are given in Table FF-1 for the three hypothetical PCB concentrations considered.

Table FF-1. Estimated Annual Individual Dermal Exposures to PCBs in Spot Remover

| PCB concentration (mg/kg) | Annual individual dermal exposures (mg/yr) |
|------------------------------|-----------------------------------------------|
| 50 | 2.1×10^{-1} |
| 25 | 1.0×10^{-1} |
| 2 | 8.4×10^{-3} |

F.F.3. Dermal Exposures to PCBs in General Household Cleaners

Maximum probable individual dermal exposures to PCBs resulting from routine use of general household cleaners are estimated in this scenario, which focuses on hypothetical household detergent formulations containing incidental PCBs. While little dermal contact occurs during routine use of laundry detergents, household detergents used for cleaning walls, floors, etc., may involve considerable dermal contact, especially if gloves are not used during cleaning operations. The presence of incidental PCBs in surfactants, fragrances, and disinfectants used in the detergent formulation could result in consumer exposure to PCBs.

The exposure calculations presented below apply to typical use of a solid household detergent designed to be mixed with water for routine cleaning jobs. The following assumptions were made:

- 96 g of detergent is used per cleaning job (based on manufacturer's recommendation for a popular product). Detergent is mixed with 1 gallon (3.785 l) of water in a bucket.
- Detergent contains 25 percent by weight of the PCB-contaminated chemical. This estimate is based on formulations given in Gosselin et al. (1976) for anionic surfactants in cleaning products.
- A 0.0024 cm* thick film of the cleaning solution remains on the hand and part of the forearm, covering a skin surface area of 500 cm², after each immersion. Therefore, 0.0024 cm x 500 cm², or 1.2 cm³ (1.2 ml) of solution remain on the skin.
- Detergent is used once a week for a total annual frequency of 52 times a year.
- One hand is immersed 20 times in the bucket during weekly cleaning sessions.
- All PCBs in the solution remaining on the skin after each immersion are available for dermal absorption.

*This is the measured film thickness for a solution of 50% water/50% bath oil retained on the skin after immersion of hands into the solution followed by a partial wipe with a rag (Versar 1983b).

The following equation estimates dermal exposure in this scenario:

$$\begin{array}{ccccccc} \text{Amount PCBs} & & \text{PCBs available} & & \text{Frequency} & & \text{Absorption} \\ \text{Absorbed} & = & \text{for absorption} & \times & \text{of exposure} & \times & (\%) \\ (\text{mg/yr}) & & (\text{mg/event}) & & (\text{events/yr}) & & \end{array}$$

where

$$\text{PCBs available for absorption (mg/event)} = A \times B \times C \times D$$

A = [PCB] in constituents (mg/kg)

B = Aqueous dilution of detergent; quantity detergent per volume of water (kg/ml)

C = Weight fraction of PCB-contaminated constituent

D = Volume of solution on skin per immersion (ml/event)

Frequency = 20 immersions per week x 52 weeks per year = 1,040 events/yr

Absorption = 100 percent.

The results of this analysis are presented in Table FF-2 for the three hypothetical PCB concentrations selected.

Table FF-2. Estimated Annual Dermal Exposures to PCBs in General Household Cleaners

| PCB concentration in chemical (mg/kg) | Annual individual dermal exposures (mg/yr) |
|------------------------------------------|-----------------------------------------------|
| 50 | 4.0×10^{-1} |
| 25 | 2.0×10^{-1} |
| 2 | 1.6×10^{-2} |

F.F.4. Dermal Exposures to PCBs in Liquid Sanding Products/Paint Removers

Potential dermal exposures to PCBs resulting from routine consumer use of sanding aids/paint removers are estimated here. This class of product is of concern because relatively large volumes are required for typical home projects and because some products contain pure chlorinated solvents that are potential sources of incidental PCBs. Moreover, considerable dermal contact may occur during routine use when protective gloves are not used.

The following assumptions were used in estimating annual individual dermal exposure:

- A PCB-contaminated solvent constitutes 100 percent of the product. This estimate is based on formulations in Gosselin et al. (1976).
- The density of the product is approximately 1.6 g/ml.
- In the process of using a saturated cloth or steel wool to administer these products, one quarter of the skin surface area of one hand (110 cm²) is coated with a 0.0024 cm* thick solvent film, or 0.26 ml of solvent.
- These products are used in biannual paint stripping projects. (This assumption is based on informal survey of people who frequently refinish furniture.)

*This is the measured film thickness for a solution of 50% water/50% bath oil retained on the skin after immersion on hands into the solution followed by a partial wipe with a rag (Versar 1983b).

Annual individual exposures were calculated using the following equation:

$$\begin{array}{rcccl} \text{Amount PCBs} & & \text{PCBs available} & \text{Frequency of} & \text{Absorption} & \text{(FF-3)} \\ \text{absorbed} & = & \text{for absorption} & \text{exposure} & \text{x} & \\ \text{(mg/yr)} & & \text{(mg/event)} & \text{(events/yr)} & \text{(\%)} & \end{array}$$

where

$$\text{PCBs available for absorption (mg/event)} = A \times B \times C \times D$$

$$A = [\text{PCB}] \text{ in product (mg/kg)}$$

$$B = \text{Quantity of product on skin (ml/event)}$$

$$C = \text{Density of product (g/ml)}$$

$$D = \text{Conversion factor; } 10^{-3} \text{ kg/g)}$$

Frequency = Twice a year

Absorption = 100 percent.

Annual individual dermal exposures calculated in this scenario are presented in Table FF-3 for the three hypothetical PCB concentrations considered.

Table FF-3. Estimated Annual Individual Dermal Exposures to PCBs from Consumer Use of Liquid Sanding Products/Paint Removers

| PCB concentration in product (mg/kg) | Annual individual dermal exposures (mg/yr) |
|-----------------------------------------|-----------------------------------------------|
| 50 | 4.2×10^{-2} |
| 25 | 2.1×10^{-2} |
| 2 | 1.7×10^{-3} |

References

Gosselin RE, Hodge HC, Smith RP, Gleason MN. 1976. Clinical toxicology of commercial products, 4th ed. Baltimore, MD: Williams & Wilkins Co.

Versar. 1983a. Draft consumer exposure scenarios for methyl chloroform products. File Memorandum No. 715-M-198. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances. Contract No. 68-01-6271.

Versar. 1983b. Exposure assessment for retention of chemical liquids on hands. Preliminary draft report. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances. Contract No. 68-01-6271.

ATTACHMENT GG

Hypothetical Consumer Exposure to PCBs in Aerosol Products

G.G.1. Introduction

The purpose of this attachment is to estimate maximum probable inhalation exposures to PCBs in common aerosol and other spray products used by consumers. PCB-containing organic chemicals may potentially be used in spray product formulations as pigments, resins, propellants, solvents, disinfectants, fragrances, and pesticides/fungicides. Consumers may be exposed to the PCBs in spray products by inhalation of airborne mists during use.

G.G.2. General Approach to Exposure Estimation

Two general spray product exposure scenarios were developed to represent maximum probable individual exposures to the range of products commonly used by consumers. Obviously, the quantity of product used, the PCB concentration in the product and in ambient indoor or outdoor air, and the frequency of exposure vary considerably among products. The two generic exposure scenarios presented in this attachment include:

1. Aerosol product used in relatively large quantities infrequently (spray paints and household pesticides).
2. Aerosol product used in relatively small quantities on a regular basis (disinfectants and similar products).

The maximum probable individual exposures associated with each scenario are calculated for three or four hypothetical PCB concentrations in the contaminated constituent(s) using appropriate formulation factors. Hypothetical PCB concentrations of 2 mg/kg, 25 mg/kg, and 50 mg/kg were used in all scenarios. A PCB concentration of 150 mg/kg

was included in calculations for the pigment constituent of products because PCB levels in diarylide and phthalocyanine pigments reportedly reach 150 mg/kg (DCMA 1982).

G.G.3. Spray Scenario 1: Applicable to Spray Paints, Household Pesticides, and Other Products with Similar Use Patterns

This spray scenario provides estimates of maximum probable individual inhalation exposures to PCBs from aerosol products which are used in relatively large quantities at a time but infrequently over the course of a year. The exposure estimates presented here are thus applicable to consumer use of spray paints and similar products, as well as to consumer use of household pesticides. Appropriate formulation factors for the PCB-containing constituents were used in the paint and pesticide applications. The following assumptions were made in arriving at exposure estimates:

- Spray paints have the following formulations of PCB-containing constituents: 1.5 percent pigment, 20 percent solvent, and 20 percent resin. (Estimates were based on informal survey of retail consumer spray paints.)
- Pesticides have the following formulation: 5 percent PCB-contaminated active ingredients and 25 percent PCB-contaminated inert ingredients. These estimates are based on an informal survey of consumer indoor/outdoor aerosol pesticide products and professional judgment concerning the likely composition of the inert portion of such products.
- 369 g of product (13 oz.) is released per use at a rate of 12 g per spray, one spray per minute over a period of 30 minutes. Sixty percent of the quantity released during each spray lands on an object (in the case of spray paints) or is otherwise unavailable for inhalation exposure because it is directed away from the consumer (in the case of pesticides). Forty percent of the quantity released per spray is distributed evenly in a 1 m³ cloud around the consumer's face throughout the duration of spray application.
- No air changes occur during use.

- The inhalation rate is 1.2 m³/hr.
- Exposure occurs only while the product is being used.
- The product is used twice a year if paint and 6 times a year if pesticide.

PCB concentrations in air resulting from spray paint or pesticide use as described above are calculated as follows for each contaminated constituent in a product:

$$\begin{aligned}
 \text{[PCB] in indoor air (mg/m}^3\text{)} &= \text{PCB in contaminated constituent (mg/kg)} \times \text{weight fraction of constituent in product} \times \text{quantity product released per spray (kg)} \quad (\text{GG-1}) \\
 &\times \text{fraction of quantity released available for inhalation exposure (0.4)} \div \text{air volume (1 m}^3\text{)}
 \end{aligned}$$

Individual annual inhalation exposures are calculated as the product of PCB air concentration (mg/m³), inhalation rate (m³/hr), duration (hr/exposure), and frequency (exposure/yr). The results of this analysis are presented in Table GG-1 and GG-2.

Table GG-1. Estimated Individual Annual Inhalation Exposures
to Spray Products: Spray Paints

| PCB in contaminated constituent (mg/kg) | PCB concentration in air (mg/m ³) | | Individual annual exposure (PCBs mg/yr) | | Total |
|-----------------------------------------------|--------------------------------------------------|----------------------|--------------------------------------------|----------------------|----------------------|
| | Pigment | Solvent or resin | Pigment | Solvent or resin | |
| 150 | 1.0×10^{-2} | NA | 1.3×10^{-2} | NA | NA |
| 50 | 3.6×10^{-3} | 4.8×10^{-2} | 4.3×10^{-3} | 5.8×10^{-2} | 6.2×10^{-2} |
| 25 | 1.8×10^{-3} | 2.4×10^{-2} | 2.2×10^{-3} | 2.9×10^{-2} | 3.1×10^{-2} |
| 5 | 1.4×10^{-4} | 1.9×10^{-3} | 1.7×10^{-4} | 2.3×10^{-3} | 2.5×10^{-3} |

Table GG-2. Estimated Individual Annual Inhalation Exposures
to Spray Products: Household Pesticides

| PCB in contaminated constituent (mg/kg) | PCB concentration in air (mg/m ³) | | Individual annual exposure (PCBs mg/yr) | | Total |
|-----------------------------------------------|--------------------------------------------------|----------------------|--------------------------------------------|----------------------|----------------------|
| | Active ingredients | Inert ingredients | Active ingredients | Inert ingredients | |
| 50 | 1.2×10^{-2} | 6.0×10^{-2} | 4.3×10^{-2} | 2.2×10^{-1} | 2.6×10^{-1} |
| 25 | 6.0×10^{-3} | 3.0×10^{-2} | 2.2×10^{-2} | 1.1×10^{-1} | 1.3×10^{-1} |
| 2 | 4.8×10^{-4} | 2.4×10^{-3} | 1.7×10^{-3} | 8.6×10^{-3} | 1.0×10^{-2} |

G.G.4. Spray Scenario 2: Applicable to Aerosol Disinfectants and Other Aerosol Cleaning Products

This spray scenario provides estimates of maximum probable individual inhalation exposure to PCBs from aerosol products which are used frequently but in small quantities, such as various household cleaning products. The approach to estimating exposures is similar to the approach used in the previous spray scenario, but the parameter values are tailored to this type of product. The following assumptions were used:

- As a worst case, the product contains 50 percent by weight of PCB-contaminated constituents.
- Forty-six grams of the product is released during one cleaning session. This represents 1/8 of a 369 g (13 oz.) can.
- The product is sprayed at a rate of 3 g per spray, one spray per minute, over a period of 15 minutes. Sixty percent of the quantity released during each spray lands on the object being cleaned (e.g., wall, floor), and forty percent of the quantity released during each spray is distributed evenly in a 1 m³ cloud around a consumer's face throughout the duration of spray application.
- No air changes occur during use.
- The inhalation rate is 1.2 m³/hr.
- Exposure occurs only while the product is being used.
- The product is used once a week, or 52 times per year.

Equation GG-1 is used to calculate individual annual inhalation exposure. The results of this analysis are presented in Table GG-3.

Table GG-3. Estimated Individual Annual Inhalation Exposures to
 Spray Products: Disinfectants and Related Aerosol
 Household Cleaning Products

| PCB in contaminated constituent (mg/kg) | PCB concentration in air (mg/m ³) | Individual annual exposure (mg/yr) |
|-----------------------------------------------|-----------------------------------------------------|------------------------------------------|
| 50 | 3.0×10^{-2} | 0.47 |
| 25 | 1.5×10^{-2} | 0.23 |
| 2 | 1.2×10^{-3} | 0.019 |

References

DCMA. 1982. Dry Color Manufacturers' Association. Comments in response to proposed rule on manufacture, processing, distribution and use of PCBs in closed and controlled waste manufacturing processes. July 8, 1982.

ATTACHMENT HH

Hypothetical Consumer Exposure to PCBs in Foods Resulting from Incorporation of Incidental PCBs into Pesticide/Fungicide Products

H.H.1. Introduction

This attachment estimates maximum probable consumer exposure to PCBs via ingestion of foods containing PCBs formed as by-products during the manufacture of chemicals used in pesticide and fungicide formulations. Exposures to foods containing PCBs from other sources are examined elsewhere in this report. A number of organic chemicals used either as active agents or inerts (e.g., surfactants, solvents, propellants, thickeners, stabilizers) in pesticide and fungicide products are suspected of containing PCBs formed incidentally during manufacture. Therefore, some agricultural products used on food crops may contain PCBs, which could become incorporated as residues in food along with the primary agricultural chemical. This attachment estimates exposure to PCBs based on available information on food contamination by agricultural chemicals.

H.H.2. General Approach to Exposure Estimation

The calculations presented below are based on the untested assumption that the amount of incidental PCBs in foods is directly related to the total quantity of pesticides, fungicides, and industrial chemicals in those foods. Thus, we assumed that all such chemicals detected in foods as residues were contaminated with an arbitrary PCB concentration prior to becoming incorporated into the foods. This approach gives a maximum probable individual exposure estimate because it is unlikely that many agricultural and industrial chemicals contain incidental PCBs at the hypothetical concentrations used in the analysis. The foundation for the calculations is provided by data on typical daily intakes of pesticides, fungicides, and industrial chemicals collected and analyzed

by the Food and Drug Administration (FDA 1981). The FDA analyzes food contaminants in a typical American diet as part of a comprehensive food surveillance system. The analytical methodologies used by FDA can detect more than 200 pesticides and industrial chemicals and their alteration products.

Exposure was estimated for three hypothetical PCB concentrations in the pesticide/fungicide/industrial chemical product. Exposure calculations were based on the assumption that the weight fraction of PCBs in the contaminated chemical does not change between the point of manufacture/formulation and the incorporation of chemical residues into food. Thus, a pesticide contaminated with 50 mg/kg of PCBs after formulation is assumed to contribute 50 mg PCBs for every kg of pesticide residue occurring in a typical diet.

H.H.3. Estimation of Annual Ingestion Exposures

In addition to the assumptions mentioned above, the following assumptions were made in order to estimate annual individual ingestion exposures to PCBs:

- o Total daily intake of pesticides and industrial chemicals (other than commercial PCBs) is 1 ug/kg body weight/day. This is a worst case estimate based on the FDA analysis reporting a total daily intake of 0.54 ug/kg body weight/day in 1978 (FDA 1981).
- o A typical man weighs 70 kg.
- o All pesticides, fungicides, and industrial chemicals detected as residues in a typical diet are contaminated with incidental PCBs at an assumed concentration of 2 ppm, 25 ppm, or 50 ppm.

The following equation was used to calculate annual individual absorbed dose:

$$\begin{aligned}
 &\text{Amount absorbed (mg/yr)} = \text{PCB concentration in chemical residue (mg/kg)} \times \text{frequency of exposure (365 days/yr)} \times \text{total daily chemical intake (ug/kg/day)} \quad (\text{HH-1}) \\
 &\quad \times \text{body weight (kg)} \times 10^{-9} \text{ kg/ug} \times \text{absorption (\%)}
 \end{aligned}$$

The results of this analysis are presented in Table HH-1 for the PCB concentrations of interest. These results can be compared with the average annual adult intake of PCBs estimated by FDA to be approximately 0.69 mg/yr.

Table HH-1. Estimated Maximum Probable Ingestion Exposure to PCBs in Foods Resulting from PCB-Contaminated Pesticides/Fungicides

| PCB concentration in chemical residue (mg/kg) | Absorbed dose (mg PCBs/yr) |
|--------------------------------------------------|----------------------------|
| 2 | 5.1×10^{-5} |
| 25 | 6.4×10^{-4} |
| 50 | 1.3×10^{-3} |

References

FDA. 1981. Compliance program report of findings. FY'78 total diet studies - adult (7305.003). Washington, DC: U.S. Department of Health and Human Services, Food and Drug Administration.

ATTACHMENT II

Hypothetical Consumer Exposure to PCBs in Plastic Building Materials

II.1. Introduction

The purpose of this section is to estimate maximum indoor air concentrations of PCBs released from plastic materials such as wall coverings, flooring, and insulation. Some possible sources of contamination are use of contaminated monomer feedstocks and use of chlorinated blowing agents and catalysts.

This section estimates maximum hypothetical inhalation exposures in a residence containing polyurethane (PUR) insulating panels and polyvinyl chloride (PVC) flooring and wallcovering. EPA has no evidence that PCBs are present in PUR or PVC products. This scenario is intended to represent maximum hypothetical exposures to PCBs in any product made from polymeric material containing PCBs at concentrations of 50, 25, or 2 mg/kg. Polyurethane and polyvinyl chloride were used in this scenario for the following reasons:

- In order to estimate the migration rate of a diffusant from a polymer, a specific polymer-diffusant system must be identified. PUR-PCB represents a system with a relatively high diffusion coefficient and, consequently, a high rate of PCB migration. PVC-PCB represents a system with a low-to-medium diffusion coefficient depending on the degree of plasticization of the system.
- Both polymers are used to make products that may be found in homes in large quantities.
- Sufficient information is available on these polymers to estimate rates at which PCBs will migrate from the polymers.

II.2. Quantity of PCBs Available for Release into a Hypothetical Residence

The following assumptions were used to estimate the quantity of PCBs available for release into a residence:

II.2.1. PCBs introduced in polyurethane

- Rigid PUR panels are used as insulation in the external walls of a residence. These panels are produced in a factory. PCBs are introduced in a halogenated blowing agent.
- The halogenated blowing agent is 13 percent by weight of the final product (see Table II-1, footnote c).
- The panels are 8 cm thick (see Table II-1).
- The residence has 6 rooms and a total volume of 230 m³ (JRB 1982).*
- The height of each room is 2.5 m and the total area of the floor is 92 m². The dimensions of each room are 4 x 4 m.*
- The total outside wall area is 2.5 m x 4 m x 10 less 10 percent for windows and doors or 90 m².*
- The volume of PUR insulation is 8 cm x 900,000 cm² = 7,200,000 cm³.
- The density of the insulation is 0.04 g/cm³ (see Table II-1).

Therefore, at concentrations of 50, 25, and 2 mg/kg of PCBs in the blowing agent, there will be 1,872 mg, 936 mg, and 75 mg of PCBs in the insulation, respectively.

*The product of floor area and room height is actually greater than 230 m³ due to error introduced in rounding numbers.

Table II-1. Properties of Polymer-Trichlorobiphenyl Systems

| Property | Rigid PUR foam | PVC (unplasticized) | PVC with 30% by weight di (2-ethylhexyl) phthalate |
|------------------------------------------------------------------------|---------------------------------|-------------------------|-------------------------------------------------------|
| Density of polymer (g/cm ³) | 0.04 ^a | 1.5 ^b | 1.2 ^b |
| Maximum weight percent of PCB-containing material in the product | 13 ^c | 60 ^d | 60 ^d |
| k^e | 5.4×10^{-3} | 3.5×10^{-5} | 3.5×10^{-5} |
| D_p (cm ² /s) | 6×10^{-8} ^f | 10^{-17} ^g | 2×10^{-12} ^h |
| Y | | | |
| • $t = 1$ yr | 8.4×10^3 | 4.2×10^6 | 9.5×10^3 |
| • $t = 10$ yrs | 2.7×10^4 | 1.3×10^7 | 3.0×10^4 |
| • $t = 70$ yrs | 7.0×10^4 | 3.5×10^7 | 7.9×10^4 |
| L (cm) | 8 ⁱ | 0.16 ^j | 0.16 ^j |
| ψ | | | |
| • $t = 1$ yr | 0.03 | 1.2×10^{-8} | 2.5×10^{-3} |
| • $t = 10$ yrs | 0.3 | 1.2×10^{-7} | 2.5×10^{-2} |
| • $t = 70$ yrs | 2.1 | 8.6×10^{-7} | 0.17 |
| a (cm) ^k | 2.4×10^5 | 3.7×10^6 | 3.6×10^6 |
| $\alpha = \frac{aK}{L}$ | 160 | 810 | 810 |
| ψ/α^2 ^l | 1.2×10^{-6} | 1.8×10^{-14} | 3.8×10^{-9} |
| Fraction of PCBs released | | | |
| • After 1 yr | 0.20 | 1.2×10^{-4} | 0.056 |
| • After 10 yrs | 0.60 ^m | 3.9×10^{-4} | 0.18 |
| • After 70 yrs | >0.95 ^m | 1.0×10^{-3} | 0.46 |

^a Schwartz and Goodman. 1982.

^b Typical values for unplasticized and plasticized PVC. Modern Plastics Encyclopedia. 1979-80. To simplify calculations, the density of PVC-containing plastic is assumed to be 1.35 g/cm³ in this attachment.

^c Halogenated blowing agents may be used in proportions as high as 30 to 40 parts per hundred parts of resin (Modern Plastics Encyclopedia, 1979-80). Assuming that (1) the blowing agent is used at a level of 30 pph of polyol and (2) toluene diisocyanate (a crosslinking agent) is used at a level of 100 pph of polyol for rigid foams, the weight percent of blowing agent in the polymer will be about 13 percent (30/230x100).

Table II-1. (Footnotes, continued)

- d PVC products usually contain many additives such as large amounts of plasticizers, stabilizers, and copolymers.

- e $K = \frac{\text{Concentration of migrant in air at equilibrium}}{\text{Concentration of migrant in polymer at equilibrium}}$

The concentration of the migrant in air at equilibrium was determined from the ideal gas law discussed in Section D of this report. For this estimate, the vapor pressure of 2',3,4-trichlorobiphenyl at 25°C (1×10^{-4} torr) was used. The concentration is estimated to be 1.4 mg/m^3 or $1.4 \times 10^{-9} \text{ g/cm}^3$. Since the saturation concentration of trichlorophenyl in the polymers is unknown, it is assumed to be equal to the maximum concentration of PCBs in the polymeric product as postulated in this scenario. This assumption will produce overestimates of the migration rate if partitioning effects are important.

$$K (\text{polyurethane}) = \frac{1.4 \times 10^{-9} \text{ g/cm}^3}{(50 \times 10^{-6}) (0.13 \text{ kg PCBs/kg PUR}) \times (0.04 \text{ g PUR/cm}^3)}$$

$$= 5.4 \times 10^{-3}$$

$$K (\text{unplasticized PVC}) = \frac{(1.4 \times 10^{-9} \text{ g/cm}^3)}{(50 \times 10^{-6}) (0.6) \times (1.35 \text{ g/cm}^3)}$$

$$= 3.1 \times 10^{-5}$$

- f ADL (1984). Estimated from Figure 4.2 and Table 4.3.

- g ADL (1984). Estimated from Figure 4.1.

- h ADL (1984). Section 5.9.

- i The thickness of rigid PUR panels ranges from about 1 to 15 cm (Schwartz and Goodman 1982). The average is 8 cm.

- j Bomberger 1980.

- k a is the ratio of the volume of the external phase to the volume of the polymer. a has been calculated for a period of 1 year, assuming that the residence undergoes 0.87 complete air exchanges per hour. Although this is time-dependent, a period of 1 year was chosen as a worst case. Thus, the volume of the external phase is $230 \text{ m}^3 \times 100^3 \text{ cm}^3/\text{m}^3 \times 0.87/\text{hr} \times 24 \text{ hr/d} \times 365 \text{ day/yr} \times 1 \text{ yr} = 1.8 \times 10^{12} \text{ cm}^3$. The volumes of the rigid PUR foam and the PVC polymers are given in Section II.2.

- l Ψ/α^2 is calculated for one year only. For a 10-year migration period, Ψ/α^2 will be one order of magnitude lower.

- m After 10 years, the concentration gradient in the polymer will have decreased, putting the PUR-PCB system into another domain (Domain 4 in ADL 1984) where the thickness of the polymer begins to affect the migration rate. The rates shown here were taken from Figure 3.5 in ADL (1984) rather than having been calculated from Equation II-5.

II.2.2. PCBs introduced in polyvinyl chloride

- All of the walls and floors are covered with polymeric wall coverings and flooring containing 60 percent by weight PVC resin. All PVC resin contains PCBs at 50, 25, or 2 mg/kg. The source of PCBs is assumed to be contaminated feedstocks used in the PVC production process.
- The thickness of the polymeric material is 0.16 cm (Bomberger 1982).
- There are 92 m² of flooring in the residence and 216 m² of wall covering (2.5 m x 4 m x 4 walls x 6 rooms less 10 percent for doors and windows).
- The volume of polymer in the residence is $(216 + 92) \text{ m}^2 \times 0.16 \text{ cm} \times 10,000 \text{ cm}^2/\text{m}^2 = 493,000 \text{ cm}^3$.
- The density of the polymer depends on the degree of plasticization and the density of other additives. The density is assumed to range from about 1.2 g/cm³ for plasticized polymer to about 1.5 g/cm³ for unplasticized polymer. To simplify the calculations in this attachment, the density of PVC-containing plastic is assumed to be 1.35 g/cm³.

The quantity of PCBs in the PVC polymer will thus be 20,000 mg if the PCB concentration in the PVC is 50 mg/kg, 10,000 mg if the concentration is 25 mg/kg, and 800 mg if the concentration is 2 mg/kg.

II.3. Estimated Migration Rates of PCBs from Polymeric Materials

Migration rates of chemicals from polymeric materials can be estimated using the methods in ADL (1984). ADL (1984) presents a series of tests to determine which processes control the diffusion rate. The processes considered are diffusion of the migrant through the polymer, diffusion of the migrant through the external phase (in this case indoor air), diffusion of the migrant through a stagnant boundary layer between the polymer and external phase, and partitioning effects, which slow migration as the concentration in the external phase approaches saturation.

The first test is the Y test, which is performed when the external phase is a fluid to determine whether the external phase is well mixed or whether boundary layer diffusion is a factor influencing migration:

$$Y = kK (t/D_p)^{1/2} \quad (\text{II-1})$$

k = Mass transfer coefficient which measures the degree of agitation of the external phase (cm/s).

K = Partition coefficient; ratio of additive concentration in external phase to additive concentration in polymer at equilibrium.

t = Time period of interest (s).

D_p = Diffusion coefficient of migrant in polymer (cm²/s).

k was estimated using the following equation (ADL 1984):

$$k = \frac{D_e h}{\lambda} \quad (\text{II-2})$$

D_e = Diffusion coefficient of migrant in external phase (cm²/s).

h = Heat transfer coefficient in enclosed environment (Btu/hr-ft²-°F).

λ = Thermal conductivity of air (Btu/hr-ft-°F).

The PCB migrant in this scenario was assumed to be trichlorobiphenyl. D_e was estimated to be $0.052 \text{ cm}^2/\text{s}$ using the method of Wilke and Lee described in Lyman et al. (1982).

At ambient temperature, h is typically $0.6 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$ and λ is typically $0.015 \text{ Btu/hr-ft-}^\circ\text{F}$ (ADL 1984). Thus,

$$k = \frac{(0.052 \text{ cm}^2/\text{s}) \times (0.6 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}) \times (1 \text{ ft}/30.5 \text{ cm})}{(0.015 \text{ Btu/hr-ft-}^\circ\text{F})} = 0.068 \text{ cm/s}$$

The values of K and D_p are unique to the specific polymer-migrant system and are shown in Table II-1 along with the calculated values of Y .

Table II-1 contains estimates for migration periods of 1, 10, and 70 years. All values for Y are well above 10, and boundary layer diffusion will not be a factor in any of these cases.

The next step in the methodology is to determine whether polymer thickness and partitioning effects are important by examining two dimensionless groups, Ψ and Ψ/α^2 , which are defined as follows:

$$\Psi = D_p t / L^2 \quad (\text{II-3})$$

where D_p and t have already been defined and L is the thickness of the polymer.

$$\alpha = \frac{aK}{L} \quad (\text{II-4})$$

where a is the ratio of the volume of the external phase to the volume of the polymer.

Values of Ψ and Ψ/α^2 for the three systems under consideration are shown in Table II-1. If Ψ is less than 0.2 and Ψ/α^2 is less than 0.0025, the system falls in the domain where the only diffusion through the polymer controls the rate of migration. This is the situation where the highest migration rates occur, and all three

systems meet these criteria for migration during the first year. The fraction of PCBs that will be released in a given time period is expressed as follows:

$$\text{Fraction of PCBs released} = 2 (\Psi/\pi)^{1/2} \quad (\text{II-5})$$

Table II-1 shows the fraction of PCBs that will have been released from PUR and PVC after 1, 10, and 70 years.

II.4. Concentration of PCBs in Air

As shown in Table II-1, the quantity of PCBs released per year is highest in the first year and decreases each year thereafter. To simplify calculations, an average concentration over 70 years of exposure will be estimated.

The following assumptions have been used to estimate the average concentration:

- The PUR panels will remain in place for 70 years. All PVC materials will be removed after 10 years.
- Ninety-five percent of the PCBs in the insulation will be released over 70 years.
- From 0.039 to 18 percent of the PCBs in the PVC materials will be released over a period of 70 years. (These PCBs will actually be released in a 10-year period. However, since releases are averaged over 70 years for purposes of estimating maximum hypothetical exposure, the actual duration of release is irrelevant.)
- The air exchange rate in the house is assumed to be 0.87 changes/hr. This is the weighted average of the air exchange rates for 4- and 6-room dwellings (JRB 1982).
- The mass of PCBs in the polymeric materials and the volume of the house are estimated in Section II.2.

Based on the assumptions listed above, the estimated average PCB concentration over 70 years can be calculated as follows:

$$\text{Concentration} = \frac{(\text{fraction of PCBs released}) \times (\text{mass of PCBs})}{(\text{volume of home}) \times (\text{air exchange rate}) \times (613,200 \text{ hrs})}$$

PCB concentrations estimated according to the above scenario are shown in Table II-2.

Table II-2. Average Concentration of PCBs in Air Over
a 70-Year Period

| Concentration of PCBs in component (mg/kg) | PCBs in PUR (mg) ^a | PCBs in PVC | | Average concentration over 70 years (mg/m ³) |
|-----------------------------------------------|----------------------------------|-------------------|------------------------------------|-------------------------------------------------------------|
| | | (mg) ^a | PCBs released (mg) ^b | |
| 50 | 1,872 | 20,000 | 1,786 - 5,378 | 1.5x10 ⁻⁵ to 4.4x10 ⁻⁵ |
| 25 | 936 | 10,000 | 893 - 2,689 | 7.3x10 ⁻⁶ to 2.2x10 ⁻⁵ |
| 2 | 75 | 800 | 72 - 215 | 5.9x10 ⁻⁷ to 1.8x10 ⁻⁶ |

^a Estimated in Section II.2.

^b Estimated by assuming that 95 percent of the PCBs in PUR are released over a 70-year period and that releases of PCBs from PVC range from 0.039 percent to 18 percent, depending on the degree of plasticization of the PVC.

II.5. Estimation of Individual Exposures

The following assumptions were used to estimate the maximum hypothetical inhalation exposure of an individual to PCBs released from plastic building materials:

- The individual weighs 70 kg and has an average breathing rate of 0.79 m³/hr (Versar 1982).
- The individual spends 73 percent of his or her time at home (Versar 1982).

The results are shown in Table II-3.

Table II-3. Maximum Hypothetical Exposure to PCBs in Plastic Building Materials

| Concentration of PCBs in the component (mg/kg) | Average concentration of PCBs in air (mg/m ³) | During period of exposure (mg/yr) | Estimated individual exposure (mg/kg/day) | Lifetime average (mg/kg/day) | Duration of exposure (yrs) |
|------------------------------------------------|-----------------------------------------------------------|----------------------------------------------|----------------------------------------------|----------------------------------------------|----------------------------|
| 50 | 1.5x10 ⁻⁵ to 4.4x10 ⁻⁵ | 0.08 to 0.22 | 3.1x10 ⁻⁶ to 8.6x10 ⁻⁶ | 3.1x10 ⁻⁶ to 8.6x10 ⁻⁶ | 70 |
| 25 | 7.3x10 ⁻⁶ to 2.2x10 ⁻⁵ | 0.04 to 0.11 | 1.6x10 ⁻⁶ to 4.3x10 ⁻⁶ | 1.6x10 ⁻⁶ to 4.3x10 ⁻⁶ | 70 |
| 2 | 5.9x10 ⁻⁷ to 1.8x10 ⁻⁶ | 3.0x10 ⁻³ to 9.1x10 ⁻³ | 1.2x10 ⁻⁷ to 3.6x10 ⁻⁷ | 1.2x10 ⁻⁷ to 3.6x10 ⁻⁷ | 70 |

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